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Instrumental Monitoring of Non-methane Hydrocarbons at a Hazardous Waste Incinerator

Little (Arthur D.), Inc., Cambridge, MA

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INSTRUMENTAL MONITORING OF NON-METHANE HYDROCARBONS AT A HAZARDOUS WASTE INCINERATOR

Prepared by

K.T. Menzies and J.W. Adams
Arthur D. Little, Inc.
Cambridge, Massachusetts 02140

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Project Officer

Merrill D. Jackson
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT The report gives results of instrumental monitoring of non-methane hydrocarbons at a hazardous waste incinerator. The objective of this field program was to evaluate the reliability of non-methane hydrocarbon analyzers as a continuous indicator of the destruction and removal efficiency (DRE) of such an incinerator. During the 5-day test, two such analyzers were evaluated. During the tests, the sample conditioning/analysis system operated reasonably well. As part of the Resource Conservation and Recovery Act (RCRA), the U.S. EPA has promulgated regulations for facilities that treat hazardous wastes by incineration. Compliance with the performance standards specified in the regulations is demonstrated by conducting a trial burn, which involves measurement of particulate emissions, hydrochloric acid emissions, and DRE for the principal organic hazardous constituents (POHCs) of the waste. During subsequent routine operating burns, carbon monoxide is the only chemical species for which effluent concentrations are monitored. It may be desirable to supplement this measure of overall combustion efficiency with an organic monitoring technique that could provide a more direct measure of POHC emissions and, thus, of DRE.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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CONTENTS

Abstract. iii
Figures vi
Tables. vi
Summary 1

1. Introduction. 8
2. Conclusions 11
3. Experimental Results. 12
   Instrumental Monitors. 12
   Sample Interface/Conditioner 14
   Field Monitoring 19
   Destruction and Removal Efficiency (DRE) 33

References. 36
Appendices

A. HNU Systems, Inc. Model PI-201 Specifications 37
B. Columbia Scientific Industries Corporation, Model HC500-2E Specifications 41
C. Beckman, Inc. Model 402 Specifications. 45
D. Operation and Maintenance Manual for the NSI Combustion Gas Monitor. 54
E. Scott Specialty Gases Analytical Report 58
F. Vapor Dilution/Handling System. 59
G. Field Data. 66

Pages iii and iv blank.

FIGURES

Number		Page
1	Sample Conditioning/Analysis System.	3
2	Comparison of NMOC (CSI or HNU) vs. THC (Bec).	6
3	Comparison of Organic Carbon vs. CO.	7
4	Probe-Tip Filter Arrangements.	16
5	Sample Conditioning/Analysis System.	21
6	Schematic Diagram of the Cincinnati MSD Incinerator	22
7	Comparison of NMOC (CSI or HNU) vs. THC (Bec).	31
8	Comparison of HNU vs. CSI.	32
9	Comparison of Organic Carbon vs. CO.	34

TABLES

Number		Page
1	Evaluation of Heat-Traced (95°C) Sample Interface.	20
2	Summary of Incinerator Test Results	24
3	Incinerator Operating Conditions.	26
4	Instrument Calibration Data	29

SUMMARY

The principle objectives of this program were to evaluate the reliability of non-methane hydrocarbon analyzers as a continuous indicator of hazardous waste incinerator performance. The tasks undertaken included:

1. The fabrication of a sample extraction/conditioning system for transfer of combustion gas to the hydrocarbon analyzers;

2. Evaluation of the reliability of two non-methane hydrocarbon analyzers under conditions of continuous operation at a hazardous waste incinerator; and

3. Determination of the correlation of non-methane hydrocarbon concentrations with combustion efficiency.

TEST FACILITY

The hazardous waste incinerator utilized for this field program is operated by the Cincinnati Metropolitan Sewer District (MSD) and is located at 1600 Gest Street in Cincinnati, Ohio. The incinerator is equipped with a rotary kiln rated at 55×10^6 kJ/hr and a cyclone furnace rated at 65×10^6 kJ/hr. Although the kiln is designed to handle solid or semisolid wastes, only liquid wastes were fired throughout the testing. The kiln and furnace are connected to a single combustion chamber to provide residence time for the combustion gas. Gases leaving the combustion chamber are quenched with water and passed on to a Venturi scrubber for particulate removal and through a sieve tray caustic

scrubber for HCl removal. From the sieve tray scrubber, the gases are directed through a mist eliminator before they leave the stack. Liquid effluent from the scrubbing system goes to the treatment plant, and bottom ash is sluiced with water into a lagoon.

The test period extended from July 25 through July 29, 1983. During this period the waste feed was a liquid containing 11-12.5% chlorine by weight. The waste feed rate was reported to be in the range of 2920 to 3740 kg/hr (6420 to 8230 lb/hr); auxiliary fuel usage was reported to be between 2.7% and 13.6% of the waste feed rate. The mean temperature was 1220-1320^{o}C (2230-2410^{o}F).

Previous trial burn testing at this facility had demonstrated it to be in compliance with the Destruction and Removal Efficiency (DRE) performance standard when burning waste mixtures of 3-16% chlorine as long as the chamber temperature was 1093^{o}C (2000^{o}F) or higher. No additional DRE measurements were made during this work.

SAMPLE EXTRACTION/CONDITIONING SYSTEM

The sample conditioning system (Figure 1) consisted of a heated microfibre filter tube and heated Teflon transfer line (30 M in length). The system also included a splitter which permitted some of the gas to be cooled to 4^{o}C in a small refrigerated condenser. Instrument calibration was conducted by passing span and zero gas through the conditioning system.

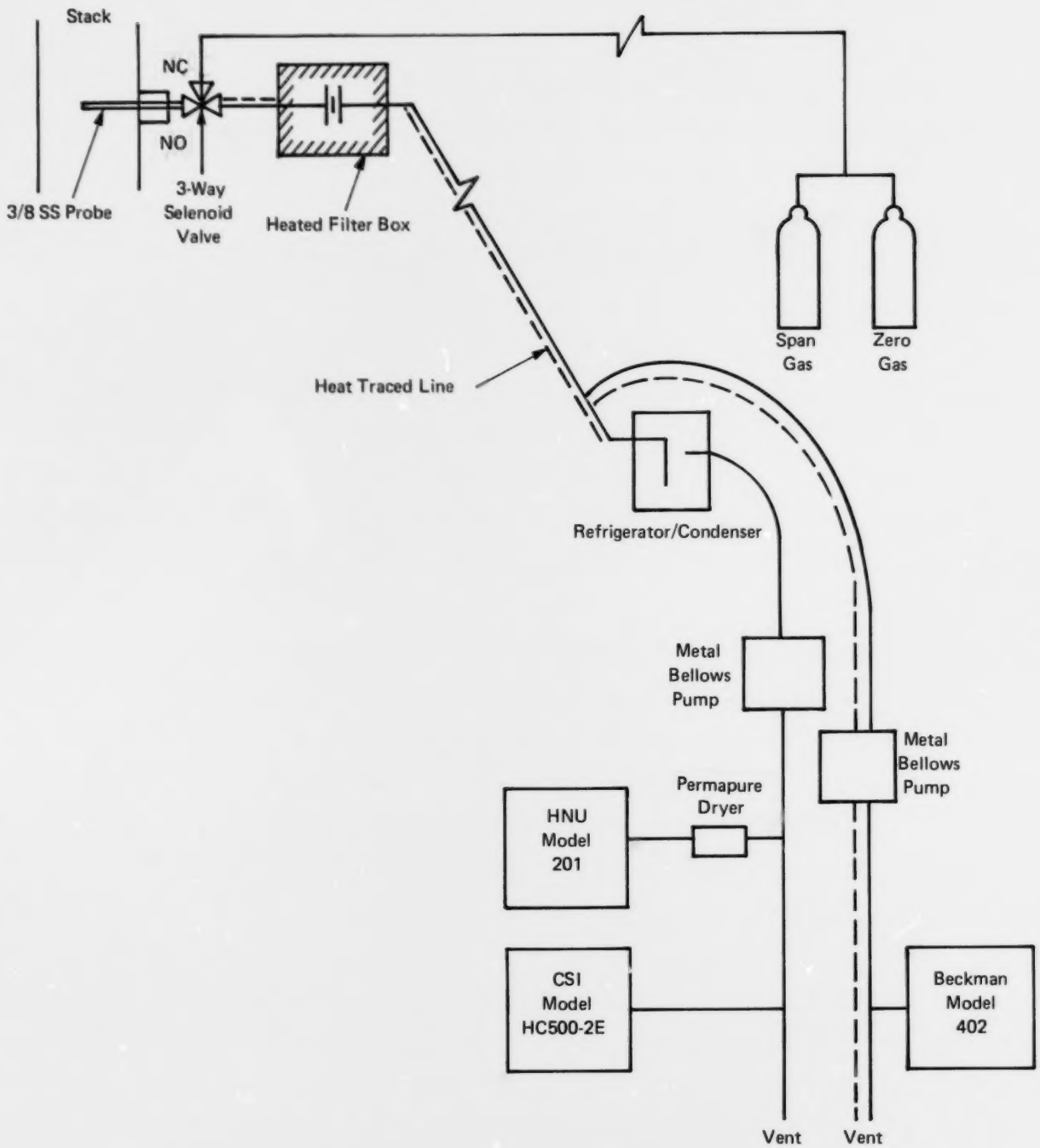

FIGURE 1. SAMPLE CONDITIONING/ANALYSIS SYSTEM

HYDROCARBON ANALYZERS

Two non-methane hydrocarbon analyzers:

1. Columbia Scientific Industries Corporation (CSI), Model 500-2E, and

2. HNU Systems, Inc. (HNU), Model 201-250

were utilized. The CSI instrument determines non-methane hydrocarbons by a difference method. A flame ionization detector (FID) is used to quantify organics in the gas sample "as received" and after treatment with a catalytic oxidizer that converts all species other than methane to carbon dioxide; the difference between these two readings gives non-methane hydrocarbons. The HNU instrument uses a detection system (photoionization detection, PID) that does not respond to methane.

A total hydrocarbon analyzer based on FID (Beckman Model 402) was used for comparative analysis of total hydrocarbons.

OTHER GAS ANALYZERS

Non-dispersive infrared analyzers were used for determination of carbon monoxide and carbon dioxide and a paramagnetic analyzer for determination of oxygen in the hot zone of the incinerator. The combustion gas was conditioned by a coarse filter and a condenser and Perma-pure dryer. This system was owned by the incinerator operator.

RESULTS OF THE TEST PROGRAM

During the five-day test period, the sample conditioning/transfer system operated reasonably well. That is, it operated 90% of the time without failure. The exception was the failure of the heater controller in the filter box. This failure was caused by vibration from the stack.

In a properly designed system, connecting the heater box to the stack with a flexible line would preclude this problem.

Calibration of the hydrocarbon analyzers with 17.3 ppm C butadiene span gas and 12% O_2 zero gas by passing the calibration gases through the conditioning system was observed to provide concentrations identical to those obtained by injecting calibration gases directly at the back of the analyzers. The observed concentrations of the span and zero gas did not vary by more than ±20% over five days.

The two non-methane hydrocarbon analyzers operated continuously (with one exception) over the five-day test period. The exception was due to a general power failure at the site.

The non-methane hydrocarbon concentrations measured by the CSI and HNU analyzers were observed to be about 20% of the total hydrocarbon concentration (Figure 2). The ratio of non-methane hydrocarbon concentrations observed by the CSI and HNU analyzers was observed to be approximately equal to one. That is, the analyzers responded approximately equally to the non-methane hydrocarbons present.

A linear correlation between the non-methane hydrocarbon concentrations and carbon monoxide concentration was not observed. Specifically, over the range of operating conditions and combustion efficiency observed in this field study, the non-methane hydrocarbon concentration appears to be independent of carbon monoxide concentration (Figure 3) and thus independent of overall combustion efficiency.

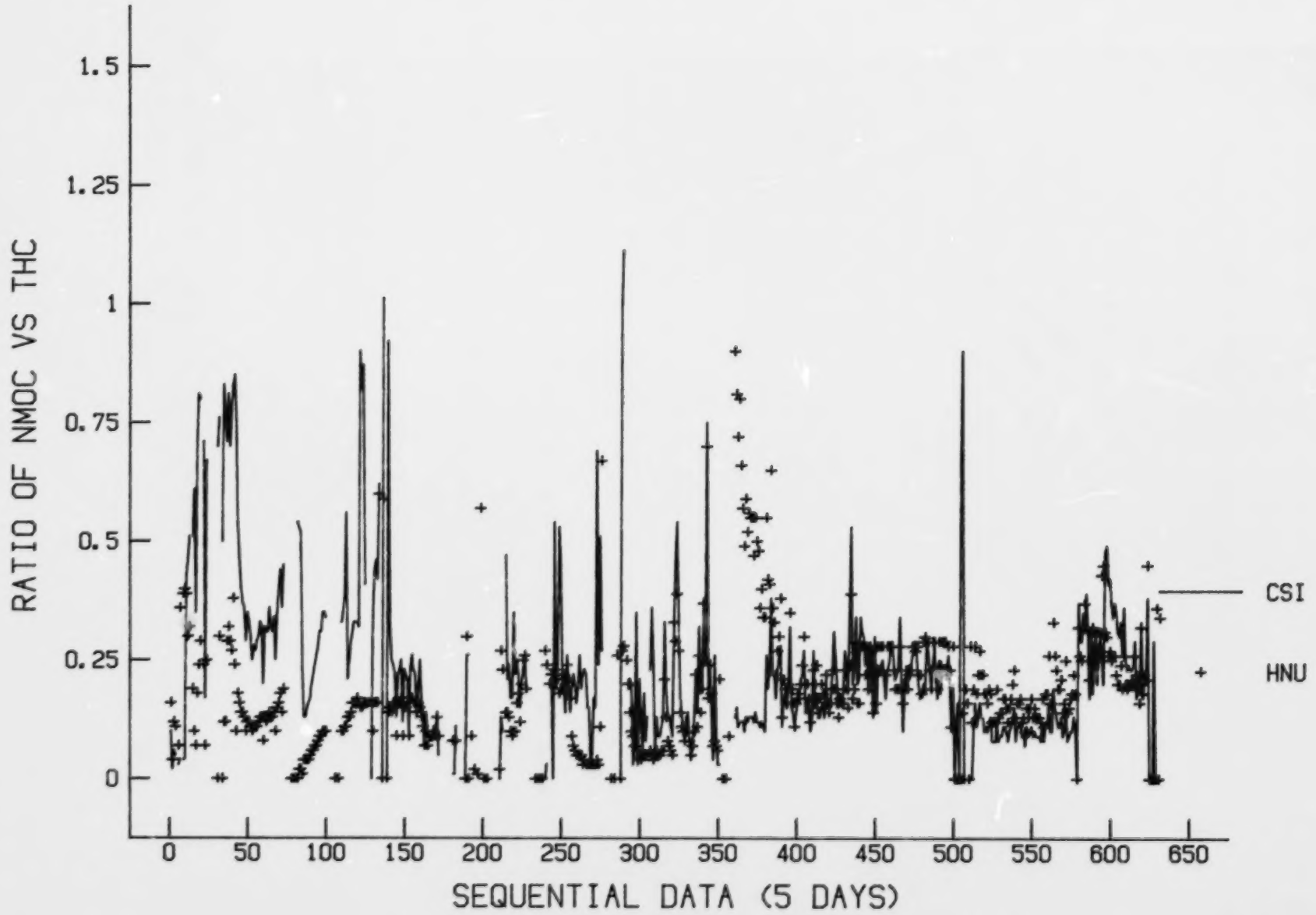

FIGURE 2. COMPARISON OF NMOC (CSI OR HNU) VS. THC (BEC)

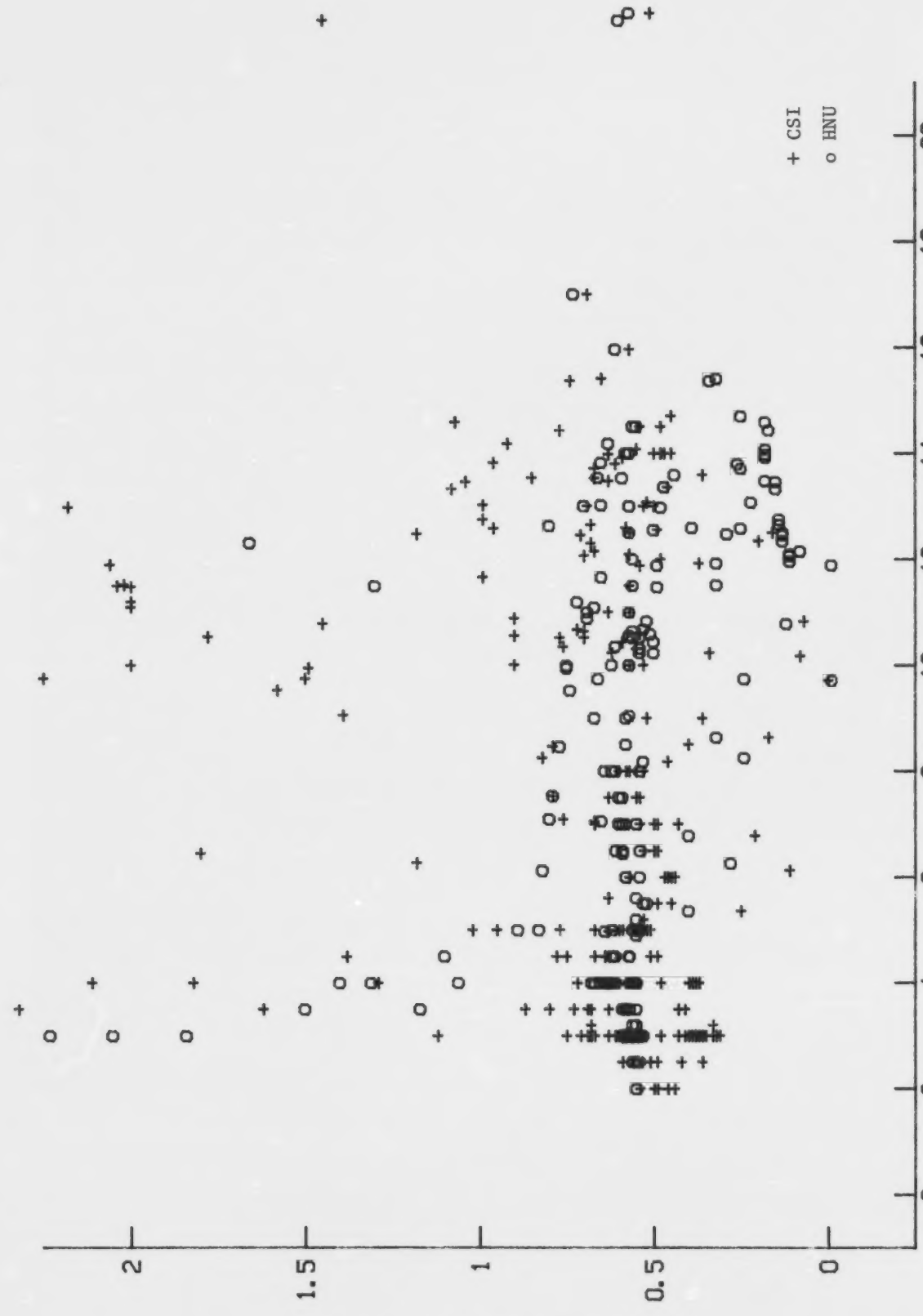

FIGURE 3. COMPARISON OF ORGANIC CARBON VS. CO

SECTION 1

INTRODUCTION

As part of the Resource Conservation and Recovery Act (RCRA), the U.S. Environmental Protection Agency (EPA) has promulgated regulations for the owners and operators of facilities that treat hazardous wastes by incineration to ensure that those incinerators are operated in an environmentally responsible manner. The regulations cover a range of activities including operational performance specifications. The performance standards for hazardous waste incinerators relate to particulate emissions (less than 180 mg/cu m or 0.08 gr/SCF), to hydrochloric acid emissions (less than 1.8 kg/hr or 4 lb/hr), and to the Destruction and Removal Efficiency (DRE) achieved for the Principal Organic Hazardous Components (POHCs) of the waste(s) being incinerated (greater than 99.99% DRE for each designated POHC). DRE is defined as:

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} \times 100\%$$

where W_{in} = mass feed rate of one POHC in the waste

W_{out} = mass emission rate of that POHC from the stack.

To demonstrate that an incinerator is operating in compliance with the performance standards requires an extensive and reasonably sophisticated set of sampling and analysis procedures.(1) The DRE performance is particularly difficult to determine because it requires that flow

rates and POHC chemical concentration data be determined simultaneously on the waste feed and on the stack effluent.

Frequent or continuous measurement of incinerator performance by the DRE criterion is expensive. Therefore, taking into account the rather extensive technical data base on hazardous waste incinerator performance (2,3), the Agency has adopted a policy that compliance with the performance standards under a given set of waste compositions and facility operating conditions may be demonstrated during a Trial Burn period. For subsequent routine operational burns, it is sufficient to document that incinerator operating conditions (including temperatures, waste and air flows, and pollution control device parameters) are within the range covered by the trial burn and to obtain continuous measurement of the level of carbon monoxide in the incinerator effluent gas.

The carbon monoxide level is considered to be an indicator of the overall Combustion Efficiency.* To the extent that DRE for organics is controlled by the overall combustion conditions, carbon monoxide may serve as a surrogate indicator of DRE.

Using carbon monoxide as a DRE surrogate is unlikely to lead to false positive results. It is generally acknowledged that any substantial increase in the carbon monoxide emission level indicates an upset in combustion conditions that would probably be accompanied by a decrease

*Combustion Efficiency (CE) is conventionally defined as:

$$CE = \frac{C(CO_2) - C(CO)}{C(CO_2)} \times 100\%$$

where C = Concentration of the indicated species in the incinerator effluent. At a constant excess air level, the concentration of carbon dioxide will be constant and CE will vary inversely with the carbon monoxide concentration.

in DRE. It is less clear whether use of carbon monoxide as a surrogate may lead to false negative results. It is possible that DRE for a particular POHC could decrease, with a concomitant increase in emission levels of that POHC, while the overall combustion efficiency and carbon monoxide emission levels remain relatively constant.

A real-time, on-line system capable of DRE determination is beyond the present state of the art. However, the objective of this work was to conduct a field investigation of the feasibility of using presently available on-line monitors for organic species in stack gas to obtain DRE-surrogate measurements that may be more relevant to POHC emissions than is a carbon monoxide measurement. There were three goals for the investigation:

1. Evaluate the reliability of a sample conditioning system and two non-methane hydrocarbon analyzers under normal incinerator operating conditions.

2. Compare the data from these two non-methane analyzers with those from a total hydrocarbon analyzer.

3. Compare the measured hydrocarbon concentrations with the carbon monoxide emission levels and combustion efficiency.

The two detection schemes that appeared potentially useful (4,5) for indirectly monitoring the DRE of POHCs were a selective catalytic oxidizer with flame ionization detector (FID; Columbia Scientific Industries Corporation Model 500-2E) and a photoionization detector (PID; HNU Systems, Inc. Model 201-250). These systems were field tested at the Cincinnati Metropolitan Sewer District hazardous waste incinerator, which had already been subjected to a Trial Burn (6) and was in routine operation.

SECTION 2

CONCLUSIONS

Conclusions drawn from the field evaluation of two non-methane hydrocarbon analyzers at a hazardous waste incinerator are given below.

1. An extractive sample conditioning system consisting of a heated microfibre filter tube, heated Teflon transfer line, and refrigerated condenser was operated successfully for sampling of non-methane hydrocarbons in the effluent stack of a hazardous waste incinerator.

2. Two non-methane hydrocarbon analyzers (CSI Corp. Model 500-2E and HNU Systems, Inc. Model 201-250) were operated reliably over a period of five days when sampling conditioned combustion gas.

3. The non-methane hydrocarbon concentrations were observed to be approximately 20% of the total hydrocarbon concentration when the waste fuel contained 11-12.5% chlorine.

4. No obvious direct correlation was observed between non-methane hydrocarbon concentration and carbon monoxide (as an indicator of combustion efficiency).

SECTION 3

EXPERIMENTAL RESULTS

INSTRUMENTAL MONITORS

The objective of this task was to evaluate suitable instrumental monitors for indirect indication of destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs) in the gaseous effluent from an incinerator stack. Specifically, the evaluation criteria included the ability to provide a continuous, simple, reliable and accurate measurement of organic (POHC) emissions from the stack during normal operation of an incinerator. Ideally, this instrument would permit quantification of an individual POHC in stack effluent, but more realistically it would provide quantification of some classes of organic compounds which are destroyed/removed with the same efficiency as the designated hazardous pollutants (POHCs) which are undergoing destruction. Concentrations of low molecular weight hydrocarbons, such as methane, in the incinerator stack are thought to be only poorly related to DRE of POHCs (unpublished data). Thus, instrumental analyzers for total hydrocarbons appear to be inappropriate. Alternatively, two particularly attractive instruments for the continuous indirect monitoring/evaluation of POHC emissions are a flame ionization detector with catalytic oxidizer for non-methane hydrocarbons or a photoionization detector which responds to aliphatic hydrocarbons other than those with molecular weight less than about 26 (C_2) - 78 (C_6).

To achieve this goal, a field evaluation program was undertaken. As a result of a previous review (4) and evaluation of volatile organic carbon detectors, the suitability of a photoionization detector, which is known to be insensitive to low molecular weight hydrocarbons, especially

methane, and a non-methane organic monitor (FID) were addressed. A total hydrocarbon analyzer (FID) was utilized as a comparative monitor.

The three hydrocarbon analyzers selected for evaluation were:

1. HNU Systems, Inc., Model PI-201-250,

2. Columbia Scientific Industries Corporation, Model HC500-2E, and

3. Beckman, Inc., Model 402.

The specifications of each instrument are given in Appendices A, B, and C, respectively.

To permit the measurement of combustion efficiency, carbon monoxide, carbon dioxide, and oxygen were also analyzed. For the three gases, two Beckman Model 864 NDIR analyzers and a Beckman Model 7550 paramagnetic analyzer were utilized, respectively. These analyzers draw a sample from the incinerator hot zone and condition it as indicated in Appendix D.

The instrumental monitors for hydrocarbons were calibrated with both certified zero gas and a certified butadiene span gas prepared by Scott Specialty Gases, Inc. (Appendix E). The zero gas (hydrocarbon free, less than 0.1 ppm) was prepared with 12% O_2 and 88% N_2 to simulate the incinerator exhaust. The butadiene span gas was prepared at a concentration of 17.3 ppm C. Generally the instruments were calibrated by passing the gases through the sampling train (heated filter and Teflon line) at four-hour intervals.

The monitors for CO, CO_2 and O_2 were calibrated with zero and span gases already available at the incinerator. These gases were prepared and certified by Matheson, Inc. The analyzers were calibrated by injection into the analyzer.

SAMPLE INTERFACE/CONDITIONER

A sample interface/conditioner was fabricated to allow sampling in the incinerator stack downstream of the ID fan. The interface was designed to limit the exposure of the instruments to excessive temperature or humidity and to eliminate particulate plugging or corrosion. The specific sampling location was selected to reduce problems which were anticipated to occur with direct sampling from the incinerator hot zone. The sampling location was also selected on the basis of a desire to monitor the gas stream as it is finally emitted after all control devices.

As noted by McNulty, et al., (7) design of an adequate extractive interface for the continuous instrumental monitoring involves a number of engineering choices and trade-offs. The objective of this program is to evaluate instruments rather than optimize an extractive interface. Therefore, a design which would provide an adequate sampling interface was selected.

The design of the sampling interface was predicated on the need to prevent particulate plugging, remove condensible water and limit hydrocarbon loss. Although it was difficult, in the absence of field test data, to recommend an optimum system which would achieve the best results, the most practical of the limited number of available options was selected for this limited field study.

Both of the analyzers selected for study are sensitive to pressure changes, and some means needed to be provided for controlling the pressure at a fixed value. The simplest method of controlling pressure was to vent the analyzer to atmosphere. Ambient barometric pressure variations are well within the tolerance limits for accuracy and were ignored. In order to control pressure by venting to atmosphere, the sample pump was positioned upstream of the analyzer.

Sample flow rate was not a critical parameter and additional flow control devices or back-pressure regulators were not found to be necessary. A flow rate on the order of 1 slpm was typical of the analyzers surveyed.

Final sample temperature was not a critical parameter as long as it remained near ambient conditions. However, the stack gas had to be cooled and dried prior to introduction into the non-methane hydrocarbon analyzers.

The proper choice of materials of construction is an important part of the interface design. Teflon and polypropylene tubing were used in most sections of the sampling train, since previous reports (7) have documented their suitability.

For combustion sources, coarse filtration of the sample withdrawn from the stack is required. Two types of filters have been used: (1) the "external" or exposed filter in which the filter element is supported within the stack and sample passes through the filter to the sample line, and (2) the "internal" or in-line filter which is also supported within the stack but is exposed only to the withdrawn sample (Figure 4). The internal arrangement is recommended when calibration gases are to be injected at the probe-tip. Internal filters are available in sizes sufficient to collect particulates over a period of several months. Therefore, automatic or semi-automatic back-flushing of the filter is unnecessary.

Calibration of the analyzer by injection of zero and span gases at the probe tip has been successfully demonstrated in several plant tests. Automatic calibration is met by using a simple timing device to actuate solenoid valves.

Information to allow proper sizing of sample lines is available. For a typical analyzer flow rate on the order of 10 slpm, 6.35 mm ID

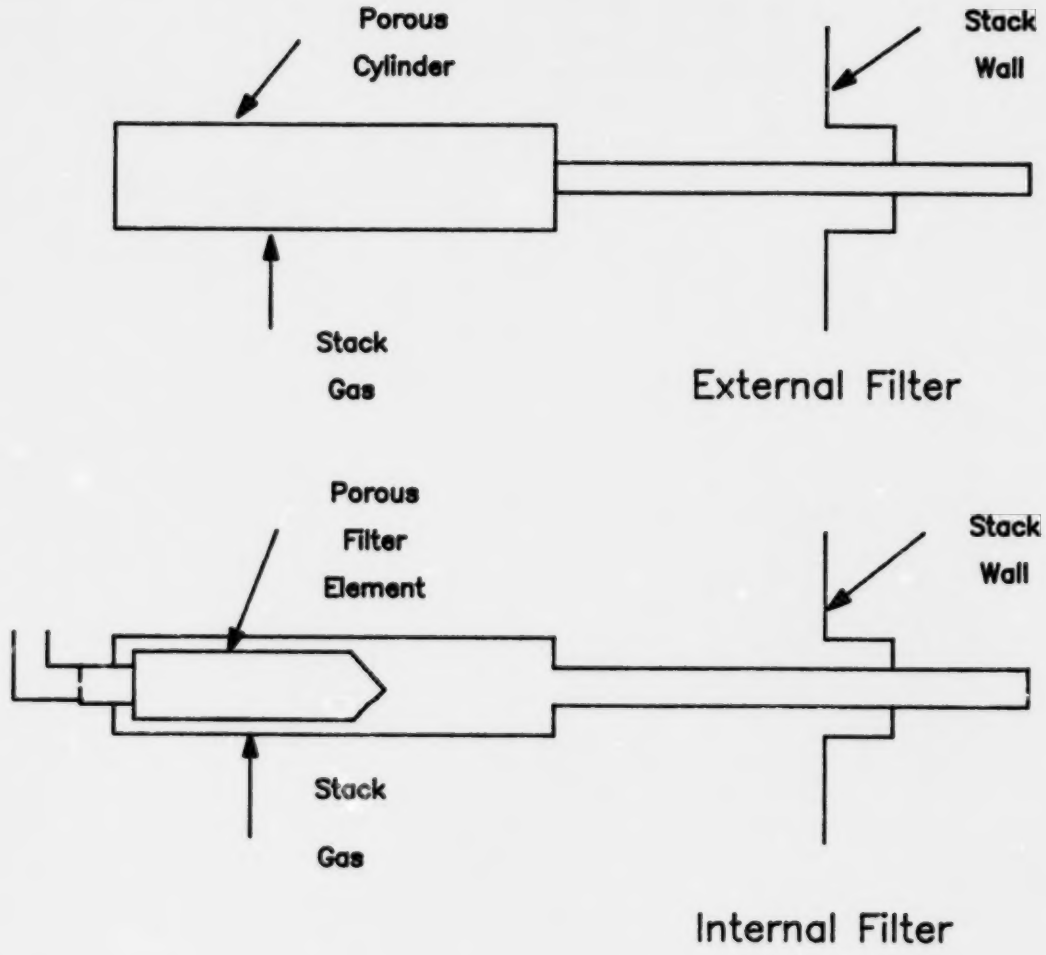

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FIGURE 4. PROBE–TIP FILTER ARRANGEMENTS

tubing is appropriate. The sample line response lag is on the order of half a minute.

When pressure is controlled by venting to atmosphere, the two most suitable types of sampling pumps are the bellows pump and the diaphragm pump. A metal bellows pump provides limited interaction of the gas stream and surface.

Moisture removal is an important part of the interface design. The unheated hydrocarbon analyzers require the maintenance of the moisture level below the dew point. A refrigerated condenser is useful for most applications where the hydrocarbons have limited solubility. Where absorption of hydrocarbons by the condensate is a potential problem, a permeation dryer can be used. The use of desiccants is not recommended. Various condensate traps and removal schemes are available.

The considerations involved in fine filtration are numerous. A number of filter media will give good particulate removal, including a tube packed with glass wool.

An important requirement of any sampling interface is that interactions between the interface and sample must not exceed certain tolerance limits. Three types of interaction, viz., reaction, absorption, and adsorption, are important.

Degradation of hydrocarbons by catalytic oxidation on particulates collected in the filter is probably negligible at 250^{o}F.

Loss of most hydrocarbons by absorption (dissolution) in condensate is also likely to be small on the basis of water/octanol partition coefficient. Other non-hydrocarbon organics could be lost here.

Adsorption on interface components can effect the system response time. Experimental tests on various sample lines indicate negligible

adsorption effects for Teflon, 316 stainless steel, and polypropylene, especially when heated.

Given these considerations and the need to condition the gas to about ambient conditions (i.e., temperature; humidity) prior to injection into the non-methane hydrocarbon analyzers, the sample interface shown in Figure 5 was fabricated. Specifically, the stack gas was drawn through a 9.5 mm OD SS probe and insulated solenoid valve and into a heated microfibre filter tube (Balston Inc., Model 100-12BH) to remove particulates. The filter was maintained at 121°C. The gas was then drawn through approximately 30 meters of 6.3 mm OD Teflon-lined, heat-traced line maintained at 95°C. Within the equipment trailer, the gas stream was split into two streams. One stream passed through a refrigerator/condensor maintained at 4°C to remove excess water from the stack gas. The other stream was maintained at 95°C until it entered the Beckman Model 402.

In order to evaluate the potential loss of chlorinated solvents in the filter and Teflon sample transfer line proposed for use at the incinerator, a test atmosphere containing carbon tetrachloride was generated in the laboratory. A concentration of approximately 0.03 ug CCl_4/L was generated in a vapor dilution system (Appendix F) by syringe drive injection and volatilization of a dilute aqueous solution of CCl_4 (i.e., 10 uL CCl_4/L H_2O). The test solution was injected at a rate of 200 uL/min into an air stream flowing at 100 L/min. A relative humidity of 82% was achieved by injection of steam at 300 mg/min. The loss of CCl_4 in a 75 M length of Teflon-lined, heat-traced line 6.35 mm ID was determined by measuring the concentration upstream and downstream of the sample filter and transfer line. The test atmosphere was drawn through the sample line at about 10 L/min with a metal bellows pump. Five replicate samples were collected with SKC, Inc. charcoal tubes from stainless steel manifolds immediately upstream and downstream of the sampling filter/line. The samples were collected at approximately 1.0 L/min for 60 minutes. The charcoal tubes were desorbed in 1 mL of

1% methanol in benzene and analyzed by GC/ECD on a 3% SP2250 GC column in accordance with NIOSH Method S314.

Initially, samples were collected while the filter box and Teflon-lined, heat-traced line were maintained at ambient temperature (23°C). The downstream concentration was observed to be 86.4% of the challenge concentration. Then, the filter box and transfer line were heated and the CCl_4 concentration upstream and downstream of the filter box (121°C) and the 75 ft heat-traced Teflon line (95°C) remeasured. The downstream concentration was observed to be equal to the challenge concentration (Table 1).

Thus, it appears likely that a heated glass fiber filter/Teflon transfer line will not remove chlorinated hydrocarbons, e.g., CCl_4, from stack gas during transfer to the hydrocarbon analyzers to be evaluated at the hazardous waste incinerator.

FIELD MONITORING

After construction and laboratory testing of the sample conditioning/analysis system (Figure 5), the two selected non-methane hydrocarbon analyzers were evaluated under actual incinerator conditions. The goal was to assess the precision, accuracy and reliability of the instrument for monitoring of non-methane hydrocarbons under typical operating conditions at a commercial hazardous waste incinerator. The field testing was conducted at the Cincinnati Hazardous Waste Incinerator. A working relationship (EPA grant) already existed with the operator of the Cincinnati facility and thus field work was greatly facilitated.

The hazardous waste incinerator operated by the Cincinnati Metropolitan Sewer District is located at 1600 Gest Street in Cincinnati. As shown in Figure 6, this incinerator is equipped with a rotary kiln and a

TABLE 1. EVALUATION OF HEAT-TRACED (95°C) SAMPLE INTERFACE

Sample No.	Challenge Concentration (ug CCl_4/L)	Observed Concentration (ug CCl_4/L)	Location
1	0.0318	0.0241	
2	0.0318	0.0288	
3	0.0318	0.0213	
4	0.0318	0.0215	Downstream of filter box
5	0.0318	0.0247	
		$\bar{X}$ = 0.0241	
		RSD = 0.126	
6	0.0318	0.0223	
7	0.0318	0.0250	
8	0.0318	0.0248	
9	0.0318	0.0266	Upstream of filter box
10	0.0318	0.0219	
		$\bar{X}$ = 0.0241	
		RSD = 0.0820	

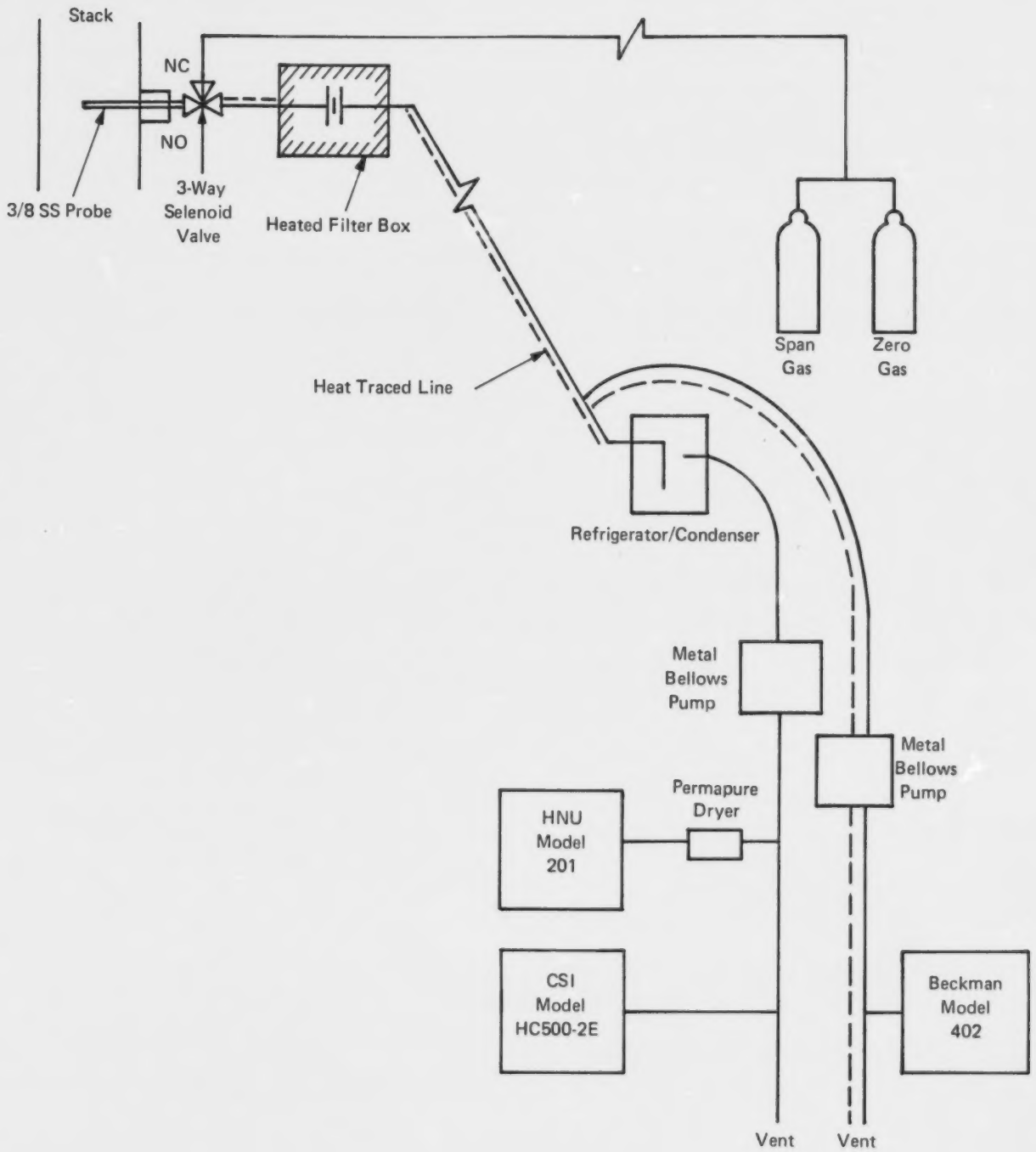

FIGURE 5. SAMPLE CONDITIONING/ANALYSIS SYSTEM

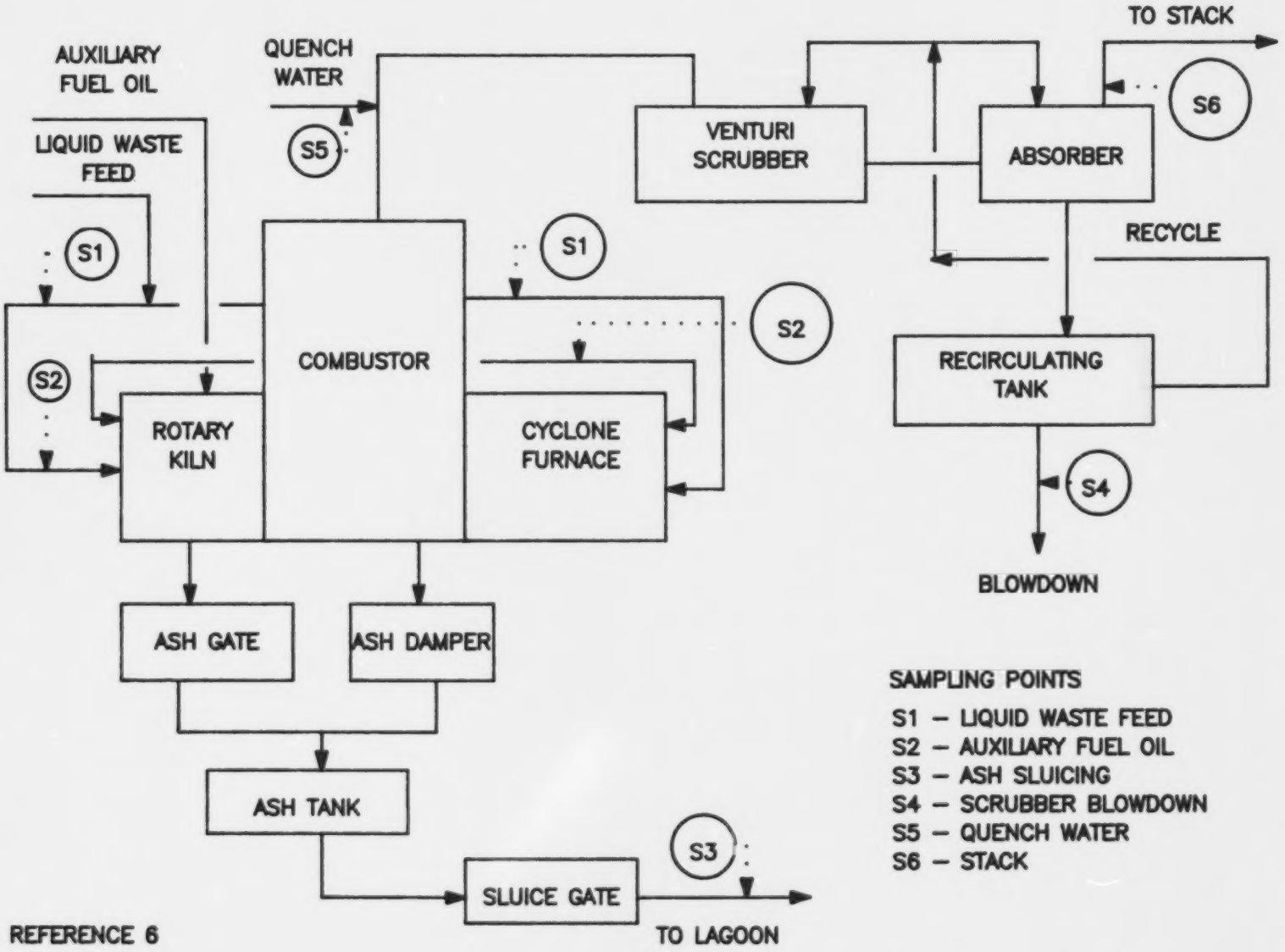

FIGURE 6. SCHEMATIC DIAGRAM OF THE CINCINNATI MSD INCINERATOR

cyclone furnace. It is designed for a total heat release rate of 120×10^6 kJ/hr (114×10^6 Btu/hr) which is split as follows:

Rotary Kiln	-	55×10^6 kJ/hr (52×10^6 Btu/hr)
Cyclone Furnace	-	65×10^6 kJ/hr (62×10^6 Btu/hr)
Total	-	120×10^6 kJ/hr (114×10^6 Btu/hr)

Although the unit does include a rotary kiln, solid or semisolid wastes are not being fed to the kiln. So far, it has been used primarily as a liquid injection incinerator, with liquid being fed into both the kiln and the cyclone furnace. The kiln and cyclone furnace are connected to a single combustion chamber that is 4.15 m diameter by 12.2 m high which provides residence time for the combustion gas. The temperature in this chamber is normally maintained above 982°C (1800°F).

Gases exiting the combustion chamber are immediately quenched with water and pass into the Venturi scrubber and then flow upward through the sieve tray scrubbing tower. Liquid feed to the Venturi scrubber and sieve tray scrubber is intended to be maintained at pH 6.0 (for HCl removal). The top of the sieve tray tower did contain a vane type mist eliminator, but this mist eliminator failed and was removed prior to this field evaluation.

Cooled gases from the scrubber are exhausted through the induced draft (ID) fan into the stainless steel stack. Liquid effluent from the scrubbing system goes to the treatment plant, and bottom ash is sluiced with water out to a lagoon.

The performance of this incinerator with regard to the RCRA performance standards has previously been examined in a study by Midwest Research Institute. The results of that study are summarized in Table 2, taken from a 1982 report (6).

During this test period, the waste characteristics and the facility operating conditions were within the ranges covered in the previous MRI

TABLE 2. SUMMARY OF INCINERATOR TEST RESULTS

Run No. / Date	Pesticide-containing waste 1 7/21/81	2 7/23/81	3 7/24/81	4 7/25/81	5 7/26/81	6 7/27/81		High chlorine waste 7 9/30/81	8 10/1/81	9 10/2/81
Waste feed rate (kg/min)	32.7	34.0	38.1	53.1	53.5	60.3		49.0	61.2	62.1
Chamber temperature (°C)	899	1093	1316	899	1093	1316		899	1093	1316
Residence time (sec)	3.3	3.7	3.4	2.2	1.8	1.7		2.3	2.0	1.5
Stack gas flow rate (dscm/min)	696	526	490	1020	1080	1010		976	1000	1160
O_2 Conc. in stack gas (%)	12.2	10.3	7.8	13.0	10.5	8.4		12.3	10.6	9.1
DRE for POHCs (%):[a]										
Chloroform	99.99	N/A	99.99	99.99	99.99	99.99	Trichloroethane	99.99	N/A	99.99
Carbon tetrachloride	99.99	N/A	99.99	99.99	>99.96	>99.9[d]	Tetrachloroethane	99.99	N/A	99.99
Tetrachloroethylene	99.99	N/A	99.99	99.99	99.99	>99.97	Bromodichloromethane	99.97	N/A	99.99
Hexachloroethane	99.99	99.99	99.99	99.99	99.99	99.99	Pentachloroethane	99.99	99.99	99.99
Hexachlorobenzene	99.99	99.99	99.99	99.99	99.99	99.99	Hexachloroethane	99.99	99.99	99.99
Hexachlorocyclopentadiene	99.99	99.99	99.99	>99.96	99.99	>99.97	Dichlorobenzene	99.99	99.99	99.99
HCl removal efficiency (%)[b]	98.5	99.4	99.7	98.5	98.1	83.8		99.5	98.7	95.3
Particulate Conc. (mg/dscm)[c]	N/A	327	N/A	N/A	146	N/A		2,230	1,710	1,130
Conc. of other pollutants										
CO (ppm)	0.6	3.6	8.2	16.8	7.0	3.0		3.3	8.9	10.6
NO_x (ppm)	122	146	118	137	136	135		132	145	130
HC^x (ppm)	2.1	3.3	1.8	1.1	0.7	1.3		0.5	1.7	0.6
Maximum Conc. of POHCs (ug/L):										
Scrubber effluent	<5	<5	<5	<5	<5	<5		<7.5	<7.5	<7.5
Bottom ash	<5	<5	<5	<5	<5	440		<7.5	<7.5	<7.5

[a] DRE values are shown only to two decimal places, using 99.99 even if calculated value was >99.99. Only the lowest value is shown.

[b] HCl based on excluding analysis of plug rinse. For Runs 7 to 9, values are estimates based on Cl analysis of MM5 trains.

[c] Particulate concentration adjusted to 12% CO_2.

[d] Due to low waste feed concentration and inadequate stack gas sample volume, DRE could not be calculated to more than one decimal place.

Reference 6

study. Data on operating conditions provided by facility personnel are presented in Table 3.

System Reliability

During the field testing, the evaluation of the selected non-methane hydrocarbon analyzers was simultaneously conducted with continuous total hydrocarbon and $CO/CO_2/O_2$ monitoring. The operating characteristics of the conditioning system/instrumental analyzers were observed over a week of incinerator operation and a typical operating condition with a waste fuel consisting of substituted aliphatic hydrocarbons containing 10-15% chlorine. The simple and reliable operation of the devices is critical to their future use in commercial incinerators. The conditioning system must remove particulates and excess moisture. The analyzers must show adequate stability with respect to drift, e.g., span, zero, and sensitivity. The FID analyzer may be negatively impacted by corrosive gases, e.g., HCl, while the PID analyzer may be negatively impacted by moisture and extended operating time. Observations of these effects was important to the evaluation.

The sample conditioning/hydrocarbon monitoring system depicted in Figure 5 was operated continuously (with several exceptions) from July 25, 1983 to July 29, 1983.

With respect to sample conditioning system problems during the week, the major observations can be summarized into the following classes:

1. The sintered metal filter probe used to filter combustion gas from the hot zone of the incinerator for analysis of major combustion gases (i.e., CO, CO_2, and O_2) was consistently plugged by fine particulates. It was successfully replaced by a coarse filter (i.e., glass wool).

TABLE 3. INCINERATOR OPERATING CONDITIONS

Day	Time	Mean Waste Organic Cl Content (% by weight)	Waste Feed Rate (kg/hour)	Total[1] Feed Rate (kg/hour)	Mean Temperature (°C)
7/27/83	PM		3740	3840	1320
7/28/83	AM	12.5	3540	3740	1300
7/28/83	PM		3390	3590	1280
7/29/83	AM		2870	3260	1300
7/29/83	PM	11.1	2920	3290	1290
7/29/83	PM		2960	3310	1220

[1]Total feed rate includes auxiliary fuel.

2. The microfibre filter tube used to filter stack gas for analysis of total hydrocarbons and non-methane hydrocarbons was replaced daily as a precaution against plugging.

3. Vibration of the heated filter box, which was firmly attached to the incinerator stack wall, led to failure of the temperature controller. However, this failure is simply an artifact of the practical decisions made to accomplish the gas conditioning for this short field study and would not occur in a properly designed (i.e., flexible connection) permanent installation.

4. During calibration of the hydrocarbon analyzers, injection of zero and span gas (17.3 ppm C butadiene) at the stack was observed to generate short-term pulses (i.e., less than three minutes) in hydrocarbon concentrations. This may indicate some small hangup of hydrocarbons in the conditioning system or pressure fluctuations. Equilibrium was apparently reached within three minutes. During filter changes, a similar pulse was observed.

5. The metal bellows pump used to draw the stack gas sample failed on one occasion. Again, it is likely that proper design of a permanent conditioning system (e.g., enlarging the diameter of the heat-traced line and reducing the number of valves in the system) would reduce the load on the pumping system and preclude overheating.

With respect to analysis system performance during the week, the following observations can be made.

1. The three hydrocarbon analyzers evaluated at the incinerator were observed to operate continuously over the five-day duration of the field study. The only exception was due to a general power outage resulting from a thunderstorm.

2. The instruments were calibrated at the beginning of the field study by injecting span and zero gas at the back of each instrument and then through the interface/-conditioning system. As indicated in Table 4, the variation between these initial calibration points is negligible. Note that after this initial calibration, all instruments were calibrated at several times during the week without readjustment of the span or zero points. Variation in span values over the five-day period were approximately $\pm$20%.

3. At the end of the field study, the detectors of both non-methane hydrocarbon analyzers were disassembled and visually inspected for degradation. No obvious deposits (condensed organics) or etching (HCl) were found. Of course, exposure of this duration may not lead to such dramatic degradation.

Hydrocarbon Data

Over 600 data points were generated from each hydrocarbon analyzer [Columbia Scientific Model 500-2E (CSI); HNU Systems Model 201-250 (HNU); and Beckman Model 402 (BEC)], and tabulated on a Monitor Labs, Inc. Model 9300 data logger. Additional data from the carbon monoxide and carbon dioxide analyzers was collected by hand. The data were then transferred to a spreadsheet file ("SUPERCALC") on a microcomputer. This

TABLE 4. INSTRUMENT CALIBRATION

Date (YYMMDD)	Time (HHMM)	BECKMAN THC		HNU NMOC		CSI NMOC		BECKMAN CO		BECKMAN CO_2		BECKMAN O_2	
		Span	Zero	Span	Zero	Span	Zero	Span	Zero	Span	Zero	Span	Zero
		CALIBRATE AT REAR OF INSTRUMENTS											
830725	2142	17.5	-0.4	20	-0.04			23.83	-25.57	4.779	-4.765	6.294	-6.133
830726	741	17.3	0	19.4	0.08								
830726	1217	16.8	-0.5	20.1	-0.03								
		CALIBRATE THROUGH SAMPLE LINE											
830726	1635			20		21.2		24.47	-25.05	4.824	-4.808	6.306	-6.211
830726	1642			20		17.3		25.07	-38.43				
830727	733	17.5	-0.9					24.99	-38.05				
830727	738			19.2		19.4							
830727	834			19.7	-0.4	17.4	-0.2						
830727	838	17.1	-0.9					28.56	-43.27				
830727	1443	15.5	0					25.2	-35.08				
830727	1447			23.5	0.1								
830727	1457					22.8	0.7						
830728	814	17.5	-0.7										
830728	818			20	0.1								
830728	827					24.9	0.01						
830729	732			16.7	0.4	15.9	-0.3						
830729	1408			16.6	0.5	17.9	0.7						
830729	1759			16.5	0.3	18	0.4						
		END CALIBRATION											

transfer greatly facilitated evaluation of the data which is included in Appendix G.

The total hydrocarbon concentrations in the incinerator stack are generally less than 10 ppm C. Initial comparisons of non-methane (NMOC) and total hydrocarbon data consisted simply of calculations of ratios of hydrocarbon concentrations as follows:

1. CSI/BEC
2. HNU/BEC
3. CSI/HNU

After excluding data collected during calibrations, several observations can be made with respect to these ratios.

1. The ("non-methane") hydrocarbon concentrations measured by the CSI Model 500 or HNU Model 201 are generally about 15-20% of the total hydrocarbon concentrations measured by the Beckman 402 (Figure 7). This is consistent with the fact that methane is not detected by the two former analyzers and that methane is generally a major component of the combustion gas.

2. The ratio of the ("non-methane") hydrocarbon concentrations measured by the CSI and HNU instruments is surprisingly close to one (Figure 8). There is no <u>a priori</u> reason for this to occur since the two instruments operate on different detection principles. However, both analyzers do respond to most organics other than methane. If aromatic hydrocarbons were a major component of the combustion gas, the HNU concentration would probably be higher than the CSI concentration since the HNU PID detector is more sensitive to aromatics than substituted aliphatic hydrocarbons. If chlorinated hydrocarbons were a significant component of the

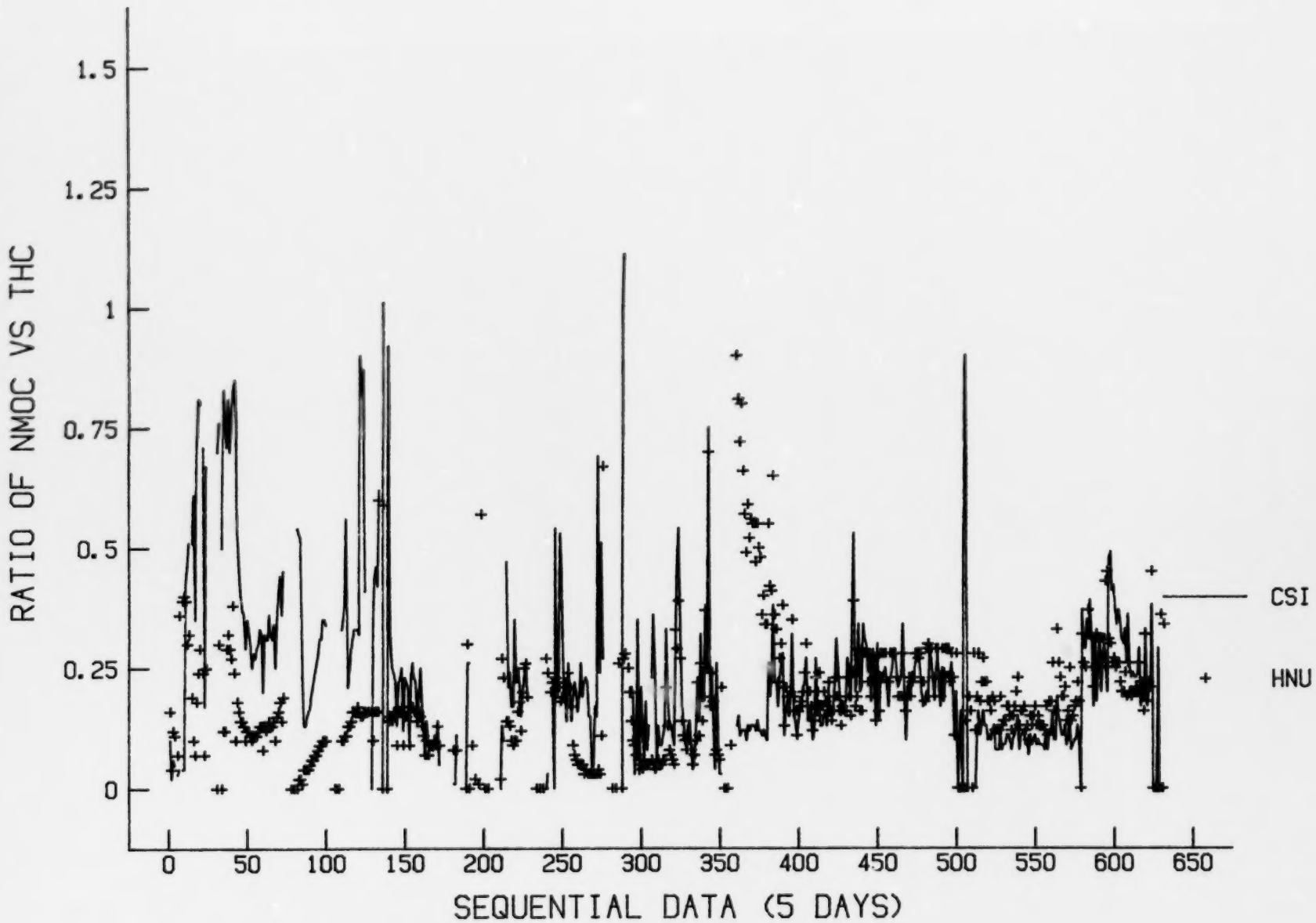

FIGURE 7. COMPARISON OF NMOC (CSI OR HNU) VS. THC (BEC)

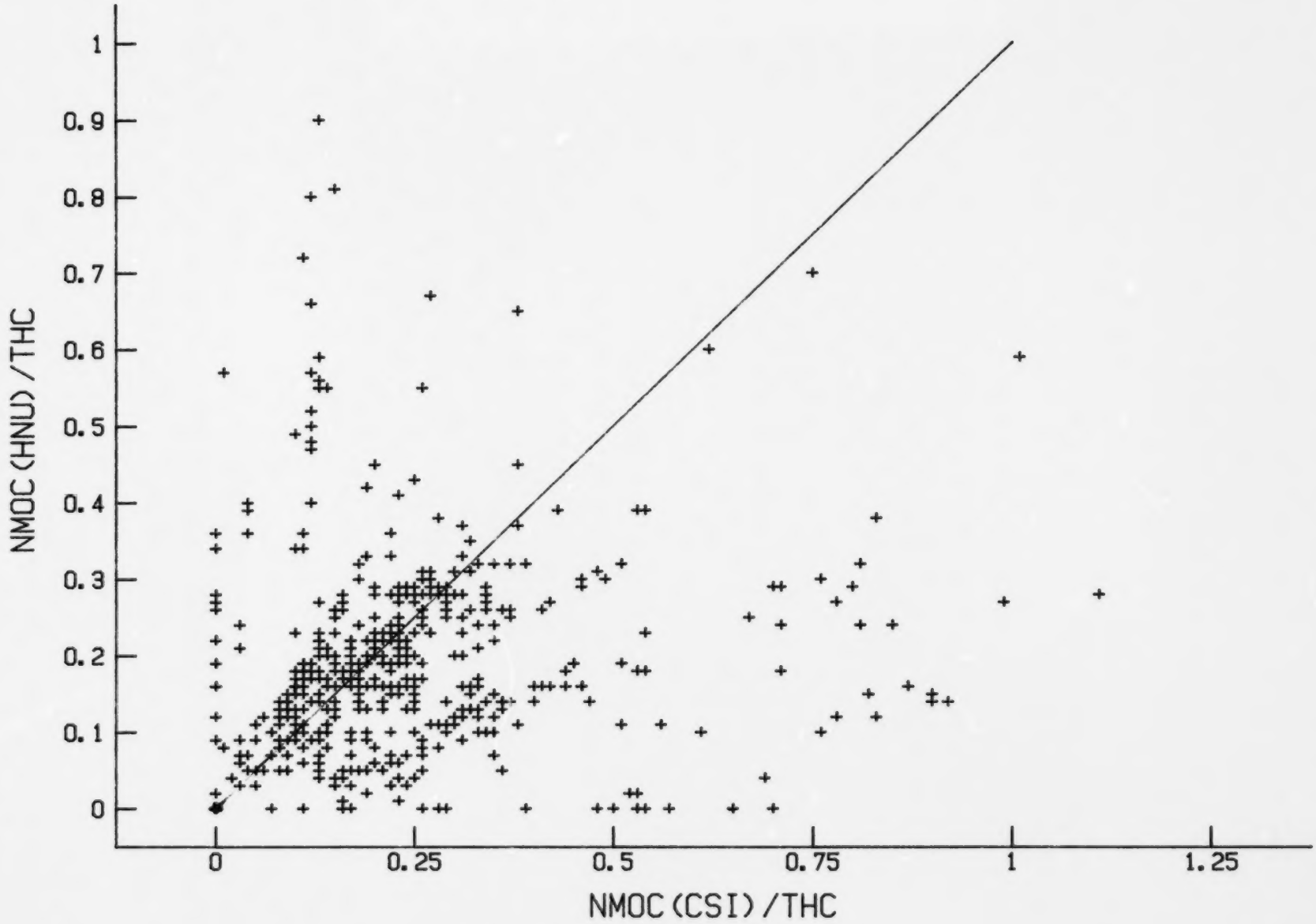

FIGURE 8. COMPARISON OF HNU VS. CSI

combustion gas, the CSI concentration might be higher than the HNU concentration due to the reduced relative sensitivity of the HNU PID for this chemical class (4). During this field study, approximately 10-15% chlorine was present in the test fuel. These observations may explain the slightly higher CSI response for most individual data points.

3. A comparison of hydrocarbon concentrations versus carbon monoxide concentration shows no obvious correlation between the two parameters (Figure 9). The organic carbon concentration (ppm C) from the Beckman analyzer varies over a range from about 0-5 ppm C while the CO concentration varies from 0-20 ppm CO. There is no obvious linear trend. The organic carbon concentration (ppm C) from the CSI and HNU analyzers varies from about 0-1 ppm C. The organic carbon concentration is apparently independent of carbon monoxide concentration. However, this observation is made over a relatively narrow range of carbon monoxide concentration. If the incinerator had been operated over a wide range of combustion efficiency (e.g., outside the state EPA permit range), some correlation might have been observed.

DESTRUCTION AND REMOVAL EFFICIENCY (DRE)

It was not possible to conduct a trial burn during this field study. Therefore, a direct comparison of non-methane hydrocarbon data with DRE is impossible. However, it was possible to collect carbon monoxide and carbon dioxide data and thus calculate combustion efficiency. It is apparent from the data that combustion efficiency in the incinerator during the field test exceeded the permit criteria of 0.9990 (Appendix G). The range observed was 0.99902 to 0.99997 while the combustion efficiency was normally above 0.9999.

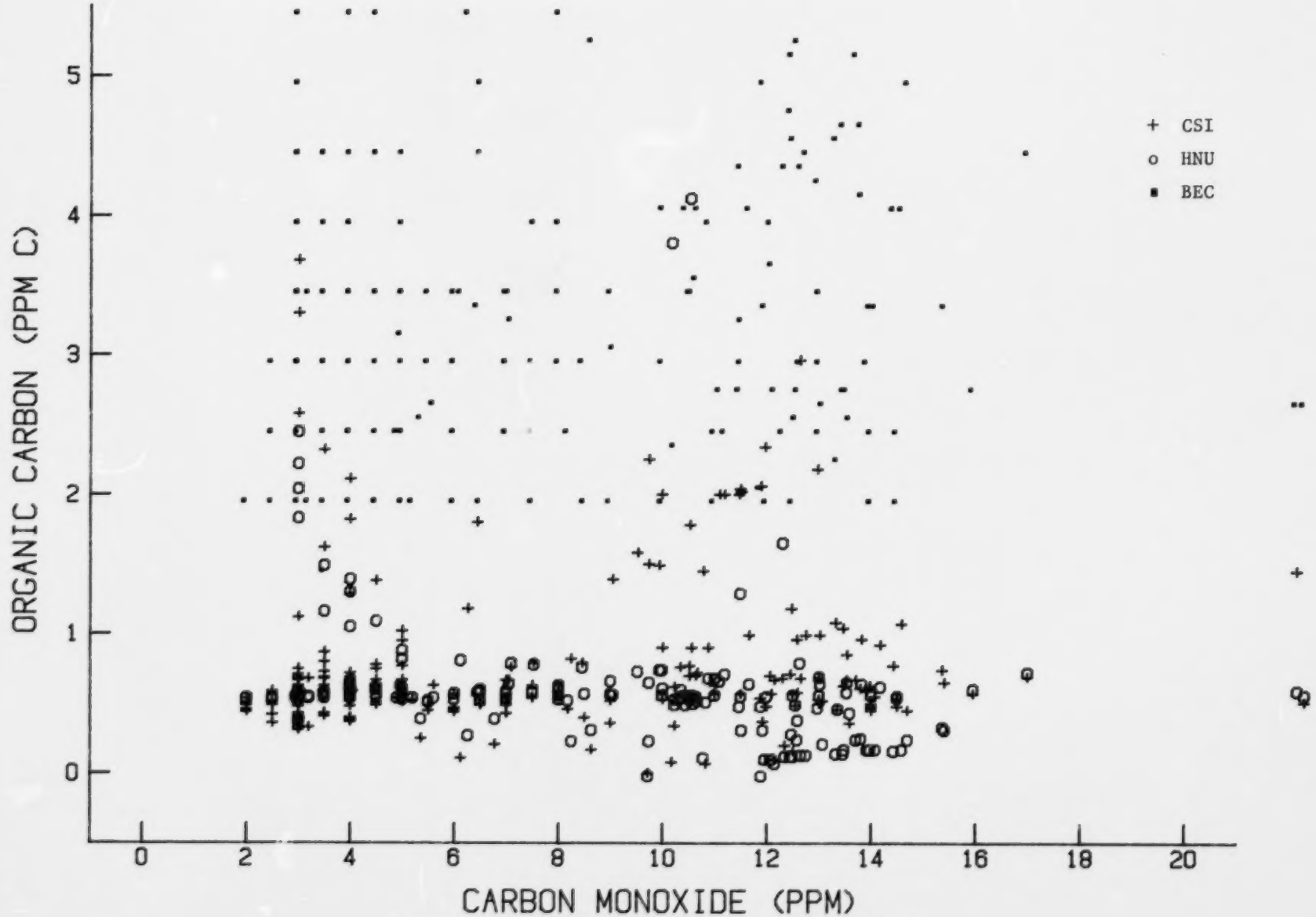

FIGURE 9. COMPARISON OF ORGANIC CARBON VS. CO

It is apparent from the field data that over the narrow range of combustion efficiency observed during the study, neither total hydrocarbon nor non-methane hydrocarbon concentrations correlate with combustion efficiency (CE) if carbon monoxide is used as an indicator of CE.

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APPENDIX A

HNU SYSTEMS, INC.

MODEL PI 201 - SPECIFICATIONS

SECTION 1

INTRODUCTION

The Model PI 201 has been designed to measure the concentration of gases in industrial or plant atmospheres, in process streams, and in stack gases. The analyzer employs the principle of photoionization for detection. This process is termed photoionization since the absorption of ultraviolet light (a photon) by a molecule leads to ionization via:

$$RH + h_v \rightarrow RH^+ + e^-$$

Where RH = trace gas

h_v = a photon with an energy $\geq$ Ionization Potential of RH

The sensor consists of a sealed ultraviolet light source that emits photons which are energetic enough to ionize many trace species (particularly organics) but do not ionize the major components of air such as O_2, N_2, CO, CO_2, or H_2O. A chamber adjacent to the ultraviolet source contains a pair of electrodes. When a positive potential is applied to one electrode, the field created drives any ions, formed by absorption of UV light, to the collector electrode where the current (proportional to concentration) is measured.

To minimize adsorption of various sample gases, the ion chamber is made of an inert fluorocarbon material, the sensor and filter are heated, and a rapid flow of sample gas is maintained through the small ion chamber volume.

The detector is heated to accept stack gas samples which have dewpoints up to 115°C. A 0.3 u glass fiber filter is incorporated in the PI 201 which removes particulate matter from the stream being measured.

The useful range of the instrument is from a fraction of a ppm to about 1500 ppm. For measurement at levels above 2000 ppm, dilution of the sample stream with clean air can be accomplished within this instrument. Some typical specifications for the Model PI 201 Photoionization Analyzer are given in Table A-1. A list of options and accessories available with this instrument is included in Table A-2. The instrument is available in the three configurations, namely, panel mount, bench and wall mount. The latter configuration is available with air purging and electrical interlock to meet Class 1 Division 1 requirements.

TABLE A-1. SPECIFICATIONS FOR MODEL PI 201 PHOTOIONIZATION ANALYZER

Performance - Benzene Referred

Useful Range:	0.1 ppm-1500 ppm
Linearity Range:	to 600 ppm
Sensitivity (max):	0-2 ppm FSD over a 100 division scale
Response Time:	<3 seconds to 90% full scale, at maximum sample pump rate
Repeatability:	±1%
Zero Drift:	<1% over 14 days
Span Drift:	<1% over 14 days
Readout:	4.5 in. (11.3 cm) meter scale
Power Requirements:	100 V, 115 V, 220 V, 240 VAC, specified by customer
Power Consumption:	200 watts, maximum

Main Controls

Range Switch sets instrument into one of three basic operating ranges chosen by customer
Lamp Switch turns off UV source for setting electronic zero
Zero for setting zero position
Span calibrates instrument to read directly in ppm of gas to be analyzed, or fine adjustment of a span gas
Recorder Output 0-5V

Auxiliary Controls

Recorder on/off for recorder
Pump on/off for pump power
Alarm on/off to activate alarm circuits

Sample Conditioning Capabilities

Heater heats sample handling components to prevent sample condensation
Sample pump rate variable up to 6 L/min (Teflon-lined diaphragm pump)
Filter 0.3 micron glass fiber, cartridge replacement, particulate matter filter

TABLE A-1. SPECIFICATIONS FOR MODEL PI 201 (Continued)

Sample Conditions

Sample dewpoint to 115°C
Sample temperature to 150°C
*Sample flow 0.5 to 5.5 L/min
*Sample pressure 12 psia to 20 psia

Ambient Conditions

The standard 201 operates with ambient temperatures up to 38°C

Construction

Designed to withstand the shock and abuse to which instruments are often subjected. The readout and sensor are housed in a steel or fiberglass case. All internal parts are aluminum, stainless steel, and fluorocarbon or inert plastics.

Serviceability

The readout and sensor are of a modular design to allow rapid servicing and/or replacement of mechanical and electrical components. All module interwiring includes terminal lug, point-to-point wire harness.

Maintenance

The instrument contains only one moving part, and consumes no gases or reagents. The only routine maintenance procedure is cleaning the light source window when required and changing the particulate filter every several weeks.

*These limits are pump dependent; other ranges are available on request.

TABLE A-2. OPTIONS AND ACCESSORIES

Several optional functions can be added to the basic 201 continuous analyzers; these include:

Strip Chart Recording. A 4.5 in. single pen recorder, manufactured by Esterline-Angus, is provided. This servomechanism recorder uses a cartridge load, fiber tip pen.

Dual Set Point Option. Both set points are adjustable O-FSD. SPDT contacts are rated at 5 A at 120 VAC.

mV to mA Output. Outputs of 4-20 mA with fully isolated 1000 volt common mode capability can be provided.

Low Pressure Option. For samples more concentrated than 5000 ppm or with dewpoints above 115°C, an air ejector or vacuum pump is required in place of the standard instrument pump.

Explosion-Proof Housings. The 201 W (wall-mounted housing) is available with special gasketing, air purge fittings with flame arrestors and a pressure interlocked power switch to conform to Class 1, Division 1 requirements of the NEC. Explosion-proof housings for all models are available.

Multi-Point Sampling Systems. Sequential samplers are available that convert the basic single-point monitor into two through twenty channel monitoring systems.

Teflon-Coated Internals. For corrosive sampling applications, all the internal metal parts are Teflon-coated to prevent loss or sample corrosion of metal parts.

UV Light Sources. The standard 201 includes a 10.2 eV light source. 9.5 and 11.7 eV light sources are available for selected applications.

APPENDIX B

COLUMBIA SCIENTIFIC INDUSTRIES CORPORATION

MODEL HC500-2E - SPECIFICATIONS

SECTION 1

INTRODUCTION

The Meloy Laboratories, Inc. Model HC500-2E Hydrocarbon Analyzer is a self-contained system for monitoring ambient concentrations of non-methane organic carbon (NMOC), methane and total hydrocarbons.

Sample air is first introduced directly into the FID detector to yield a total hydrocarbon reading which is stored in an electrical circuit. A pneumatic system is automatically switched so that the sample air passes through a catalytic converter before it is introduced into the detector. The catalytic converter converts substantially all the NMOC to a non-detectable species. Therefore, in this mode, only the methane present in the sample will be detected. The methane reading is stored in another electrical holding circuit. A differential amplifier subtracts the methane reading from the total hydrocarbon reading to provide an NMOC reading as the output signal.

The design of the Meloy HC500-2E was implemented with emphasis on obtaining stable and reliable performance and ease of service and maintenance. Precise pneumatic and thermal control of critical elements and the utilization of proven solid state circuitry contribute to the performance characteristics of the instrument.

In addition to the basic HC500-2E, Meloy Laboratories, Inc. provides a variety of options and accessories to meet most users' requirements. For example, rack mount, digital output, automatic reignite, and automatic zero/span check system are some of the options.

SECTION 2

PRINCIPLE OF OPERATION

The Meloy Flame Ionization Detector (FID) is based on the ionization of hydrocarbon molecules in a flame. Hydrocarbons are fragmented by the flame to carbon radicals; e.g., $CH^{\cdot}$. These radicals react with oxygen radicals to form positive carbon ions and electrons. The positive ions can undergo further reactions with water molecules to produce hydronium ions.

The following equations summarize some of the possible reactions:

$$C_xH_y \longrightarrow CH^{\cdot}$$

$$CH^{\cdot} + O^{\cdot} \longrightarrow CHO^{+} + e^{-}$$

$$CHO^{+} + H_2O \longrightarrow H_3O^{+} + CO$$

An 84-volt source is used to produce an electrostatic field between the ionization probe inside the burner chamber and the burner block. This causes the positively charged ions to migrate to the negatively charged probe and the negative ions to the burner block. The resulting current is proportional to the ions collected. An electrometer amplifier converts the current to voltage which is fed to the sample and HOLD circuits.

The Meloy FID is designed to optimize the sensitivity and stability of these reactions. Sample air is drawn into the detector block by means of the external vacuum pump. Hydrogen and combustion air are supplied to the FID under slight pressure by appropriate sources. All three gas streams, as well as the exhaust from the block, are regulated by means of temperature controlled orifices to provide stable flow rates to and in the burner.

The catalytic oxidizer is a solid substrate in which non-methane organic compounds are converted to carbon dioxide and water. Neither of these products respond to the FID. The temperature of the converter is held at a point where no methane is converted while nearly 99 percent of ambient NMOC compounds are converted.

SECTION 3

SPECIFICATIONS

Performance Specifications

Ranges:	0 - 5 ppm C 0 - 10 ppm C 0 - 50 ppm C 0 - 100 ppm C 0 - 500 ppm C
Minimum Detectable Sensitivity (NMOC):	0.05 ppm C
Noise (NMOC):	±0.02 ppm C
Lag Time:	Less than 15 seconds
Rise Time to 90%:*	Less than 30 seconds
Fall Time to 90%:*	Less than 30 seconds
Updating Time (Switching Time):	1 minute
Total Cycle Time:	2 minutes
Precision:	±1% full scale
Zero Drift:	±0.5% full scale/day ±1.0% full scale/3 days
Span Drift:	±0.5% full scale/day ±1.0% full scale/3 days
Linearity:	±1% full scale
Selectable Time Constant:	OFF, 1 second or 10 seconds

*This applies when analyzer is placed in the total hydrocarbon (THC) or methane continuous sampling mode.

Operational Specifications

Unattended Operation (No adjustment of flow or electrical systems):	7 days (minimum)
Sample Flow Rate:	Approximately 70 mL/min
Hydrogen Flow Rate:*	Approximately 60 mL/min at 50 psig
Combustion Air:*	Approximately 150 mL/min at 50-60 psig
Power Requirements:	115 ± 10 vac (50/60 Hz) 250 watts (includes pump)
Recorder Outputs (For each of the three channels):	0 - 100 mV 0 - 10 V 4 - 20 mA (optional)
Relative Humidity:	0 - 99%
Ambient Temperature Range:	20°C to 30°C for specified specifications

Configurational Specifications

Weight:	Less than 18 Kg (40 lbs)
Case Dimensions:	43 cm x 51 cm x 31 cm (17") W x (20") L x (12-1/4") H
Mounting Available:	Bench Rack - 48 cm (19") W (optional)
Sample Pump:**	External Vacuum Pump

*The hydrogen and combustion air must be hydrocarbon-free for best results.

**Sample is drawn into the burner and analyzed before contact with the pump is made.

APPENDIX C

BECKMAN, INC.

MODEL 402 - SPECIFICATIONS

SPECIFICATIONS

Fullscale Sensitivity - Adjustable from 5 ppm CH_4 to 10% CH_4.

Ranges - Range Multiplier Switch has eight positions: X1, X5, X10, X50, X100, X500, X1000, and X5000. In addition, SPAN Control provides continuously variable adjustment within a dynamic range of 10:1.

Response Time - Less than 1 second for 90% of final reading at oven temperature of 200°F, and less than 1.5 seconds at oven temperature of 400°F. (CH_4 sample supplied directly to analyzer inlet without sample probe.)

Electronic Stability - ±1% of fullscale per 24 hours, with ambient temperature change of less than 10°F.

Reproducibility - ±1% of fullscale for successive identical samples.

Analysis Temperature - Adjustable from 200°F to 400°F.

Ambient Temperature - 32°F to 110°F.

Ambient Humidity - 95% relative humidity.

Output - Selectable output of 10 mv, 100 mv, or 1 volt.

Safety Features - Continuous indication of burner flame status, with automatic shutoff of fuel gas in event of burner flame-out condition.

Air Requirements - 350 to 400 cm/min of clean, hydrocarbon-free air, supplied at 30 to 200 psig.

Fuel Gas Requirements - 75 to 80 cc/min of premixed fuel consisting of 40% hydrogen and 60% nitrogen or helium, supplied at 30 to 200 psig.

Electrical Power Requirements - 107 to 127 volts a.c., 50/60 Hz, 15 amperes.

Shipping Weight - 150 pounds.

Catalog Number - Beckman 194300 Model 402 High-Temperature Hydrocarbon Analyzer.

SECTION 1

INTRODUCTION

The Model 402 Hydrocarbon Analyzer is designed to measure the total hydrocarbon content of exhaust emissions from gasoline, diesel, turbine, and jet engines. The analysis is based on flame ionization, a highly sensitive detection method.

The instrument consists of:

1. Heated, temperature-controlled sample line.

2. Analyzer unit, incorporating a flame-ionization detector and associated sample-handling system, with critical sample-handling components contained within a temperature-controlled oven.

3. Electronics unit, containing an electrometer amplifier and associated circuitry, readout meter, and recorder output provisions. The electronics unit may be attached directly to the analyzer unit, or may be detached for remote mounting at a maximum distance of 75 feet.

Sample from the source is drawn into the analyzer through the sample line. To prevent the loss of higher-molecular-weight hydrocarbons, the sample is maintained at a selectable elevated temperature during its passage through the sample line and the interior of the analyzer. Temperature setpoint for both the sample line and the analyzer oven is adjustable from 200°F to 400°F via a single front-panel control.

Principal features of the analyzer and electronics units are described in Paragraphs 1.1 and 1.2, respectively.

1.1 ANALYZER UNIT

Paragraphs 1.1.1 through 1.1.5 describe various areas of the analyzer unit.

1.1.1 Flame Ionization Burner

The hydrocarbon sensor is a burner where a regulated flow of sample gas passes through a flame sustained by regulated flows of a fuel gas and air. Within the flame, the hydrocarbon components of the sample stream undergo a complex ionization that produces electrons and positive ions. Polarized electrodes collect these ions, causing current to flow through

measuring circuitry located in the electronics unit. The ionization current is proportional to the rate at which carbon atoms enter the burner, and is therefore a measure of the concentration of hydrocarbons in the original sample.

1.1.2 Sample-Handling System

A stainless-steel, bellows-type pump draws sample into the analyzer and through a glass-fiber filter that removes particulate matter. Sample is then supplied, under positive pressure, to the burner. An internal sample-bypass arrangement provides high-velocity sample flow through the analyzer, thus minimizing system response time. A front-panel flowmeter indicates bypass flow.

1.1.3 Calibration Gas System

For convenience of calibration, the analyzer has rear-panel inlet ports for connection of suitably pressurized zero and span standard gases. Flow of each standard gas is controlled by a corresponding front-panel needle valve. A front-panel three-way valve permits rapid selection of either the actual sample or the desired standard gas.

1.1.4 Oven

The oven, which uses air-bath heating, is maintained at the selected temperature by a solid-state temperature controller utilizing a thermistor sensor.

A vertical partition divides the oven into two compartments with separate doors. The left-hand compartment contains the burner, the sample pump, and the three-way gas-selector valve. The right-hand compartment contains only the sample filter. This arrangement permits convenient access to the filter without disturbing temperature equilibrium of the other elements.

1.1.5 Burner-Flameout/Fuel-Shutoff Circuitry

Within the analyzer, the fuel gas is routed to the burner through a solenoid valve controlled by the burner-flameout/fuel-shutoff circuitry. A thermistor sensor continuously monitors the status of the burner flame. In event of flameout, the valve closes to stop the flow of fuel gas; simultaneously, a front-panel indicator illuminates to alert the operator.

1.2 ELECTRONICS UNIT

The electronics unit has front-panel controls for range selection and adjustment of zero and span. Readout is on a front-panel meter calibrated linearly from 0 to 100. In addition, a selectable output of 10 mv, 100 mv, or 1 volt is available to drive a voltage-type recorder.

Solid-state modular plug-in circuit boards provide reliability and facilitate servicing.

SECTION 2

INSTALLATION

2.1 FACILITY PREPARATION

Paragraphs 2.1.1 through 2.1.4 provide information that may be required prior to installation.

2.1.1 Outline and Mounting Dimensions

Significant dimensions are given in the instruction manual (not included).

2.1.2 Interconnection Drawings

Electrical interconnection is shown in Figure C-1.

2.1.3 Location and Mounting

Analyzer Unit

The analyzer unit is designed primarily for benchtop use. Preferably it should be located in a clean area, not subject to extreme temperature variations.

Gas Cylinders

The cylinders of fuel, air, and calibration gases should be located in an area of relatively constant ambient temperature, to minimize variations in the detector background signal. Such effects are due largely to contaminants in the cylinder gases.

Electronics Unit

The electronics unit may be attached directly to the analyzer unit, or may be mounted remotely, at a maximum distance of 75 feet. Arrangements for panel and bench mounting are shown in the instruction manual.

2.1.4 Utility Specifications

Electrical power requirements are 107 to 127 volts a.c., 50/60 Hz, 15 amperes.

2.3 FUEL AND AIR REQUIREMENTS

During normal operation, the analyzer uses a fuel gas and air to maintain the burner flame. Criteria for selection of these gases are given in Paragraphs 2.3.1 and 2.3.2.

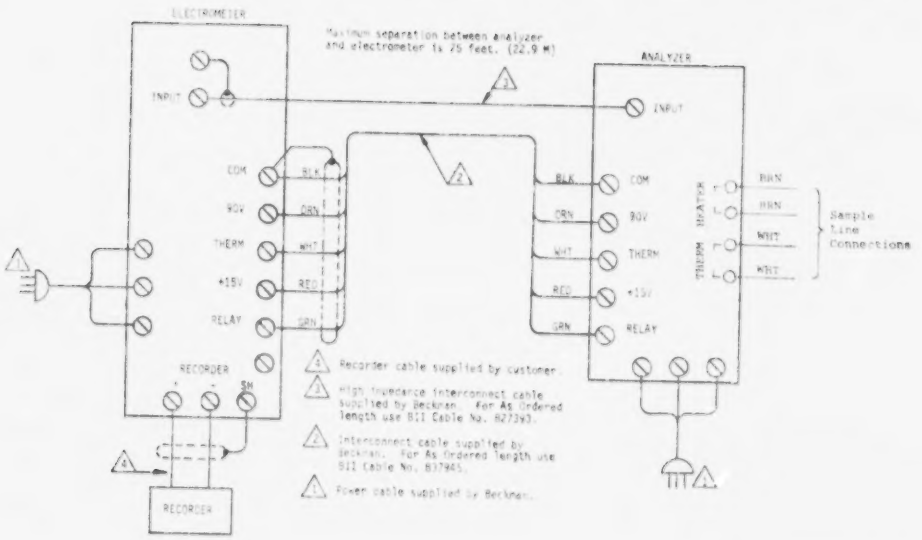

FIGURE C-1. ELECTRICAL INTERCONNECTION

In addition, the analyzer requires suitable standard gas(es) for calibration. Refer to Paragraph 3.2.1.

Preferably, each gas used should be supplied from a tank or cylinder equipped with a clean, hydrocarbon-free, two-stage regulator. In addition, a shutoff valve is desirable, particularly on the fuel cylinder. Install the gas cylinders in an area of relatively constant ambient temperature.

2.3.1 Fuel Gas

The analyzer uses a premixed fuel gas consisting of 40% hydrogen and 60% nitrogen or helium. Suitable gas mixtures are available from various suppliers. In ordering fuel gas, specify that it must be hydrocarbon--free, i.e., less than 1 ppm hydrocarbons expressed as CH_4.

2.3.2 Air

Contaminated burner air is a common cause of high background noise level. Consequently, use of a suitable pure source of air is important. The most desirable type is water-pumped (not oil-pumped) cylinder air.

2.4 SAMPLE LINE

As shown in the manual, the end of the sample line which connects to the analyzer has four attached electrical leads. These leads connect to corresponding terminals on the analyzer rear panel, as shown in Figure C-1. White leads connect to terminals designated THERM; brown leads connect to terminals designated HEATER.

The sample line connects to the SAMPLE inlet at the rear of the analyzer. To connect sample line, loosen Swagelok fitting, insert tubing through feedthrough fitting, then tighten Swagelok fitting.

Temperature for both the sample line and the analyzer oven is determined by the setting of the TEMP. ADJUST Control. A temperature of approximately 350°F is commonly used for diesel or turbine engines.

2.5 GAS CONNECTIONS

For external gas lines, the use of all new tubing throughout is strongly recommended. Copper refrigeration tubing is preferred. Stainless steel tubing is less desirable, as it contains hydrocarbon contaminants, necessitating thorough cleaning before installation.

In connecting gas-supply lines and associated fittings, use Teflon tape only. Do not use pipe-thread compound or other substance with an organic base.

Proceed as follows:

1. Check analyzer to make sure that plugs and caps are removed from all inlet and outlet fittings.

2. If sample is toxic or noxious, or is to be reclaimed, connect BYPASS outlet to suitable disposal system. Do not use any device causing back pressure on burner.

3. Clean external fuel, air, and sample lines and regulators. If stainless steel tubing is employed, heat lines with a torch to drive out contaminants before connecting lines to analyzer. Recommended method is to attach the tubing to either a nitrogen or helium cylinder through a two-stage regulator, and adjust the regulator for a low flow of gas through the tubing. Use a propane or natural gas torch to heat the tubing to at least 600°F, working the heat source slowly from the regulator end to the open end. This will remove contaminants from the inside walls of the tubing, and drive them out the open end. Do not use this method when lines are connected to the analyzer, as all contaminants will be driven into the analyzer.

4. Purge external fuel, air, and sample lines.

5. Connect external fuel and air lines to FUEL and AIR inlet fittings on analyzer. Connect external sample line to SAMPLE inlet on analyzer.

6. Adjust regulators on fuel and air cylinders (or other gas-supply sources) for appropriate output pressure. Maximum permissible pressure at AIR and FUEL inlets of analyzer is 200 psig. Minimum acceptable pressure is approximately 30 psig.

7. Check all gas connections to ensure that they are leak-free. Use of SNOOP (Beckman Part 837801) or other suitable leak-test liquid is recommended. Do not use soap or other organic substances; they will contaminate the system, resulting in excessive noise and background current.

WARNING

Be particularly careful in checking for leaks in the fuel lines. Fuel gas leakage can cause an explosion.

2.6 ELECTRICAL CONNECTIONS

> WARNING
>
> Before supplying electrical power to analyzer, complete the gas connections, and verify that fuel gas connections are leak free. Refer to Paragraph 2.5.

Both the analyzer unit and the electronics unit are supplied with power cords attached. If the electronics unit is to be left attached to the analyzer, the power cord from the electronics unit may be plugged into the a.c. outlet at the rear of the analyzer.

If the electronics unit is to be mounted remotely from the analyzer, make electrical interconnections as shown in Figure C-2.

If a recorder is used, connect leads to terminals designated RECORDER, "+," "-," and "SH" on the barrier terminal strip in the electronics unit. Move the slide switch on the output circuit board to the position appropriate to the span of the particular recorder. Options are 10 mv, 100 mv, and 1 volt.

APPENDIX D

OPERATION AND MAINTENANCE MANUAL FOR THE NSI COMBUSTION GAS MONITOR

NIAGARA SCIENTIFIC, INC.
6716 Joy Road, East Syracuse, NY 13057
(315) 437-0821

The NSI Combustion Gas Monitor is a microprocessor-based measuring system which continuously monitors and records the concentrations of oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2) in the gaseous output products from a combustion furnace. A block diagram of the system is shown in Figure D-1. The system draws a sample from the stack, filters it, analyzes it for O_2 (wet) content, dries it and then analyzes it for O_2 (dry), CO and CO_2 concentrations. The concentration of each gas is then compared to a limit value and added to previous values to allow averages to be computed. If the concentration of any gas is beyond its limit value, the system will indicate it by activating horns and lights and printing out a warning message on the teletype. In addition, the system prints out averages at timed intervals, checks itself for proper operation and recalibrates the analyzers using bottled gases.

The NSI Combustion Gas Analyzer consists of a DATKON 700CN microcomputer, four analyzers, a sample drying system, four pressure switches, a flowswitch, and all sample control valving and electronic circuitry necessary to control all parts of the system. At the heart of the system is the DATKON 700CN which is a microprocessor-based data acquisition and control system. The 700CN takes in data from the analyzers and various sensors indicating the status of the system. The sensors detect the sample, instrument air, and ZERO and SPAN gas pressures and the instrument flowrate. The 700CN then generates control signals based upon the data received, to control the lights, horns, valving and AUTO ZERO/SPAN/BACKFLUSH cycle. The front panel of the DATKON 700CN contains a 16-digit alphanumeric display and a membrane keyboard. These are used to manually control certain functions and to monitor or change various operating parameters. The display is also used to indicate what caused an alarm condition. In addition, the system comes with a TELETYPE terminal which is external to the main cabinet. This is used for hard copy printouts of the averages, warning messages, and operating parameters. The terminal can also be used to display or change various operating parameters by entering the appro-priate command.

The analyzers in the main cabinet are a THERMOX Model #WDG-III Combustion Oxygen analyzer, a BECKMAN Model #7550-02-1 Oxygen analyzer, a BECKMAN Model #865-14-13 NDIR Carbon Monoxide analyzer, and a BECKMAN Model #864-23-13 NDIR Carbon Dioxide analyzer. All operations of the analyzers are automatically controlled by the DATKON 700CN. Every four hours the analyzers are cycled through an AUTO ZERO/SPAN/BACKFLUSH calibration sequence, which flows calibration gases through the analyzers and stores the parameters used in determining the gas concentrations. These concentrations are obtained through a y=mx+b type of calculation which eliminates any long-term drift problems with the analyzers and allows them to run longer than a month without manual recalibration. The manual mode can be selected via the DATKON 700CN front panel key-board allowing the analyzers to be manually ZEROED and SPANNED with their front panel controls. At the end of the ZERO/SPAN cycle, instrument air is switched back through the sample line and filters (BACKFLUSH cycle) to blow any particulate matter out and reduce the maintenance needed in

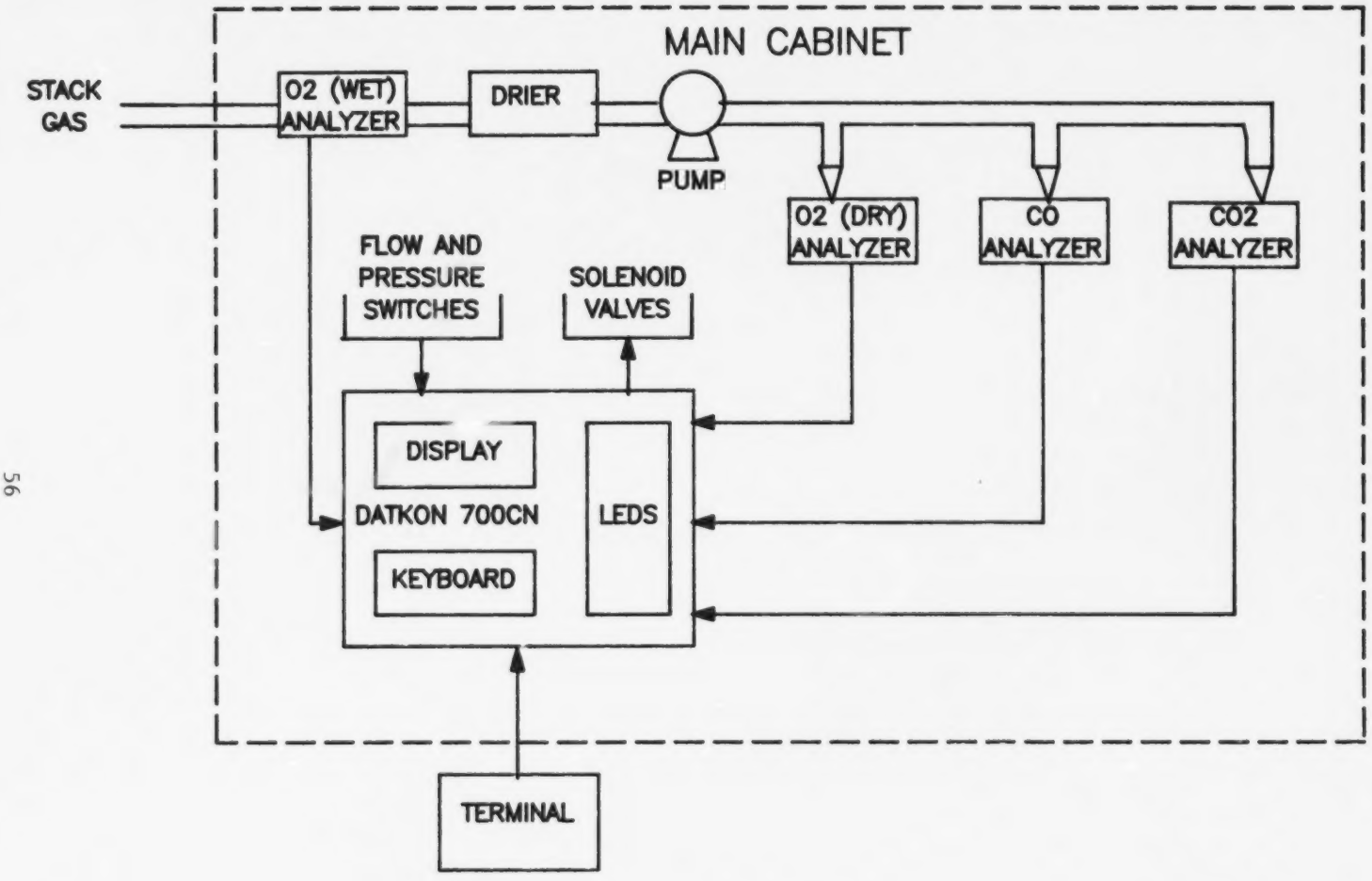

FIGURE D–1. DIAGRAM OF NSI COMBUSTION GAS MONITOR SYSTEM

keeping the filters and lines clean. The BACKFLUSH cycle is also performed at hourly intervals in between the calibration cycles.

The valving in the main cabinet consists of all components necessary to draw a sample from the combustion stack, dry it and pass it to the analyzers. This is accomplished with an inert (TEFLON/STAINLESS STEEL construction) vacuum/pressure pump which draws the sample gas and raises its pressure to the 10 PSIG needed by the analyzers. A pressure switch at the input of each analyzer is checked by the 700CN every three minutes to verify that an adequate sample flowrate exists. A low sample flowrate causes a drop in the pressure at the analyzer inputs and is indicated with a 700CN front panel LED, an audible alarm and a message displayed on the 700CN display and the terminal. A low sample flowrate could be caused by a plugged inlet filter or a damaged sample line. In addition, the main cabinet contains various solenoid valves to switch the ZERO and SPAN gases to the analyzers and instrument air for backflushing.

Ahead of the sample pump is a two-stage drying system which consists of a BALSTON Model #33 Coalescent filter and a PERMA-PURE Model #PD-1000 Drier. The coalescent filter is the first location in the sample path where the temperature is allowed to drop which causes any condensibles to liquify and be trapped out. The output of the coalescent filter is connected to the PERMA-PURE drier which consists of semi-permeable membrane tubes, with the sample gas flowing down the inside of the tubes and dry instrument air (-40^{o}C D.P.) flowing across the outside of the tubes. This drier reduces the sample moisture concentration to less than a -10^{o}C D.P. Either drier alone is capable of handling the moisture in the sample and hence a redundancy was built into the system to assure a dry sample for the analyzers. The PERMA-PURE drier, however, will dry the sample to a much lower level.

As indicated in the brief description above, the NSI Combustion Gas Analyzer has been designed to be completely automatic with the DAKTON 700CN at the heart of the system. The 700CN analyzes gas samples drawn from the stack and, in addition, runs many diagnostic routines which continuously check the condition of the entire system and indicate if a problem is encountered. It also contains routines to test the lights and horns when requested, to display and change various operating parameters and to allow manual control over the individual operations.

APPENDIX E. SCOTT SPECIALTY GASES ANALYTICAL REPORT

Scott Specialty Gases

a division of Scott Environmental Technology, Inc.

PLUMSTEADVILLE, PA. 18949 PHONE: (215) 766-8861 TWX: 510-665-9344

A.D. LITTLE
ATTN: KEN MENZIES
20 ACORN PARK
CAMBRIDGE, MA 02140

Date: JANUARY 4, 1983
Our Project No.: 318569
Your P.O. No.: 551211

Gentlemen:

Thank you for choosing Scott for your Specialty Gas needs. The analyses for the gases ordered, as reported by our laboratory, are listed below. Results are in volume percent, unless otherwise indicated.

ANALYTICAL REPORT

Cyl. No. AAL-9021 — Analytical Accuracy ±2%

Component	Concentration
1-3BUTADIENE	4.333 ppm
OXYGEN	12.49%
NITROGEN	BALANCE

Cyl. No. AAL-8619 — Analytical Accuracy ±2%

Component	Concentration
1-3 BUTADIENE	8.543 ppm
OXYGEN	12.66%
NITROGEN	BALANCE

Cyl. No. AAL-174 — Analytical Accuracy ±2%

Component	Concentration
1-3 BUTADIENE	18.10 ppm
OXYGEN	12.59%
NITROGEN	BALANCE

Cyl. No. AAL-6259 — Analytical Accuracy ±2%

Component	Concentration
OXYGEN	12.39%
TOTAL HYDROCARBON	< 0.1 ppm
NITROGEN	BALANCE

Analyst Carole Haurylko
Carole Haurylko

Approved By
Francis Nevill

CERTIFIED

The only liability of this Company for gas which fails to comply with this analysis shall be replacement thereof by the Company without extra cost.

CERTIFIED REFERENCE MATERIALS EPA PROTOCOL GASES
ACUBLEND® CALIBRATION & SPECIALTY GAS MIXTURES PURE GASES
ACCESSORY PRODUCTS CUSTOM ANALYTICAL SERVICES
TROY, MICHIGAN / SAN BERNARDINO, CALIFORNIA / HOUSTON, TEXAS

APPENDIX F

VAPOR DILUTION/SAMPLING SYSTEM

The vapor generation/dilution system used for the validation studies of several vapors and gases, such as this analyte, is shown schematically in Figure F-1. The system basically consists of a main line air stream to which are added predetermined amounts of various liquids, gases or aerosols to generate the desired vapor concentrations. From the main line, three dilution arms branch off in which the desired multiples 0.5, 1.0 and 2.0 times the OSHA standard concentration level are established. Six sampling devices are connected in parallel to the 0.5S dilution line and six to the 2S dilution line; twelve sampling devices are connected to the 1S dilution line. All these devices are connected via critical flow orifices (CFOs) to the corresponding vacuum lines.

Air flow rates through the system are established by means of critical flow orifices (CFOs) and flow restrictors. The primary air system derived from the house air compressor is maintained at 20.0 psig. The appropriate orifice diameters are chosen to maintain an air flow of approximately 0.1 cu m/min in the main line and an addition of 0.05 cu m/min to each of the dilution lines. The main line is maintained at 8 cm H_2O pressure by means of a needle valve. Appropriate flow restrictor diameters are chosen for the 0.5S, 1S, and 2S dilution lines so as to give the desired final concentrations of vapor in air.

The system was designed to generate either 4X or 2X the OSHA standard concentration in the main line. When a 4X level is generated, 0.05 cu m/min of dilution air is added to each dilution line. Orifices are selected so that the 0.5S, 1S and 2S lines have flows equal to approximately 0.007, 0.017 and 0.050 cu m/min, respectively, of the main line concentration added to the dilution air, thus giving the desired final concentrations. Where a main line concentration of 2X the OSHA standard is generated, no dilution air is added to the 2S dilution line--0.017 cu m/min is simply allowed to flow through this line--and 0.050 cu m/min of dilution air is added to the 0.050 cu m/min and 0.017 cu m/min of main line mixture admitted to the 1S and 0.5S dilution lines, respectively.

All materials which the vapor may contact before collection are 316 or 304 stainless steel. A glass heater is included where the liquids are added to the main line. Shutoff ball valves are placed in the dilution lines to allow their independent operation and the calibration of air flows. The main line has a 2.54-cm (1 in.) O.D., and the dilution lines are 1.90-cm (0.75 in.) O.D. Diameters were chosen to give turbulent flow with an approximate minimum Reynolds number of 3000.

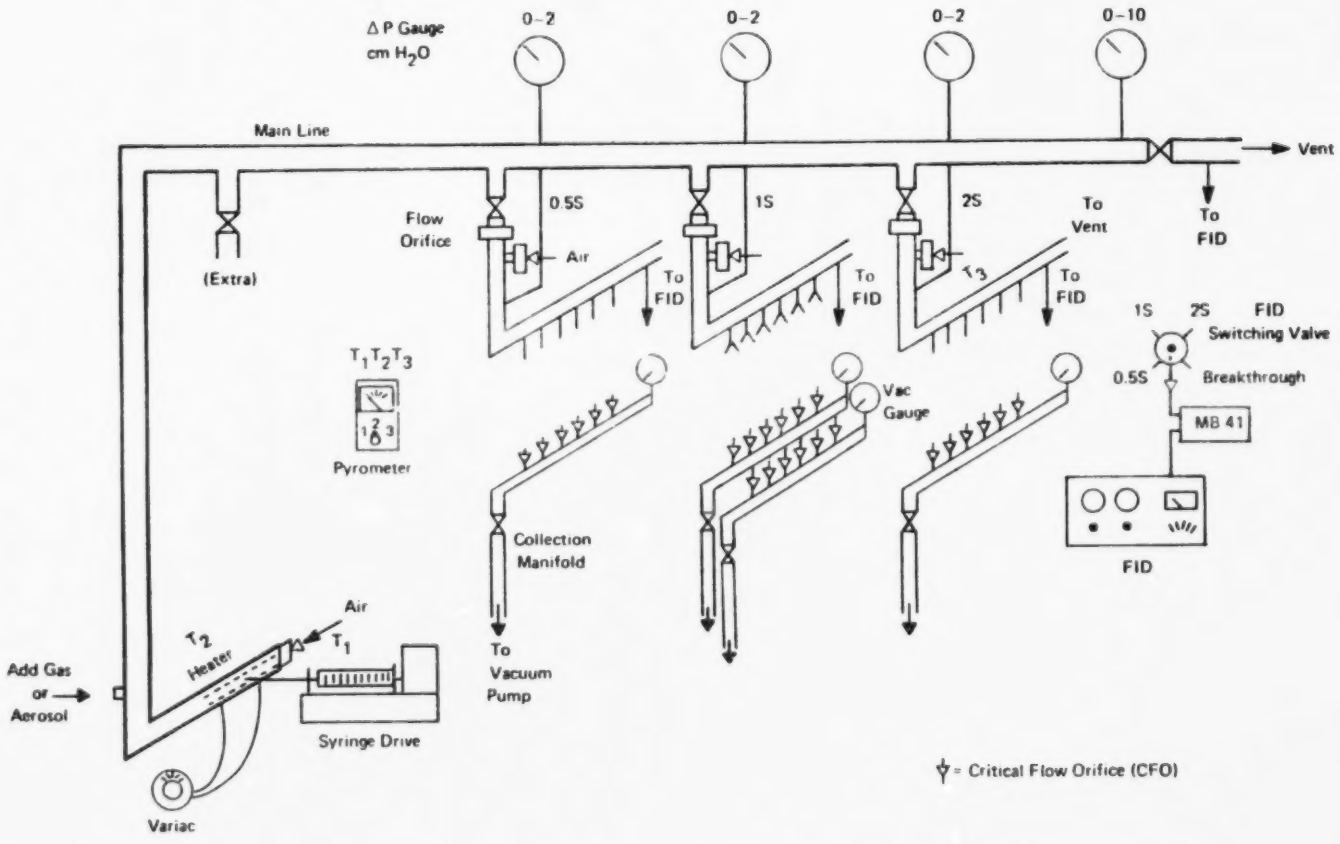

FIGURE F-1. Vapor Generation/Dilution/Sampling System

Air Supply

Air from the house compressor is treated by passing it sequentially through a cotton filter, a silica gel bed, a charcoal bed and a high efficiency glass fiber filter for removal of water, hydrocarbons, and particulate. This air is then connected to a manifold containing six takeoff ball valves. The pressure (20 psig) at the manifold is maintained with a Nullmatic Moore 40H50 regulator and monitored with an Ashcroft 0-60 psig test gauge. The air supply is used for each of the dilution system connections as well as for the flame ionization detector monitor flame and "zero" air.

Sample Collection Manifold

Sample flow through the sampling devices connected to the dilution lines is established by connecting each device by means of a short piece of flexible tubing to a CFO which is connected to a 1.27 cm (1/2 in.) O.D. vacuum manifold. Each dilution line has a separate manifold which derives its vacuum from a Model 0322 Gast vacuum pump. The orifices are jewel orifices pressed into a threaded Teflon rod. One end of the rod is screwed into a tee on the manifold, and the other has a hose tabulation fitting connected to it. The orifice is protected from plugging by means of a piece of 100 mesh stainless steel screen.

Vent System

All excess vapor-laden air is collected via a 3.81-cm (1.5 in.) PVC manifolding system where it is passed through a 0.3 x 0.3 x 0.6-M charcoal bed. Flow is established by means of a pressure blower on the exit side of the charcoal bed, and it is vented to the laboratory hood exhaust.

Calibration

Air Flows

Main Line--The air flow delivered by the Main Line CFO was determined by measurement with a Singer Dry Test Meter. The meter had previously been calibrated with a spirometer primary standard. Using the 0.310-cm diameter orifice at 20 psig air pressure, the flow was found to be 0.1086 cu m/min corrected at 25^{o}C and 760 mm Hg.

Dilution Lines--The air flow through each of the dilution line CFOs and restrictor orifices was similarly measured with the Dry Test Meter to assure that they met design parameters, but these values did not provide the primary basis for determination of vapor concentration.

Collection CFOs--Since the flow rate through the sample collection CFOs was lower (0.2 and 1.0 liter per minute) than appropriate for use with the Dry Test Meter, the flow rate of each of these orifices was

measured using an SKC soap bubble meter which was independently calibrated by gravimetrically measuring water capacity.

All volume measurements have been referenced to normal temperature and pressure of 25°C and 760 mm Hg.

Dilution Ratios

The concentration of vapor in the dilution lines is determined from the concentration calculated in the Main Line and the dilution ratio determined between the dilution lines and the main line. These dilution ratios were measured by adding a controlled amount of propane gas to the Main Line and then measuring the relative concentration in each of the lines using a Beckman Model 402 heated hydrocarbon analyzer. The procedure was repeated several times and is regularly checked during the program.

In the case where 4X or 2X concentration level conditions were generated, the dilution ratios reported below were observed.

Case Generated	Main Line	Relative Concentration		
		2S	1S	0.5S
4X	1.000	0.5097	0.2557	0.1311
2X	1.000	1.000	0.499	0.227

Each of these sets of values represents a different set of air flow and orifice selection conditions as previously discussed. Point to point comparison of the six sample ports on each manifold showed less than a 1% variation in concentration among them.

Monitors

To provide a ready check on operating conditions, several gauges or monitors have been included in the system. Dwyer Magnehelic gauges monitor the pressure on the Main Line and each of the dilution lines. A 0-10 cm H_2O gauge is used on the Main Line (Setpoint 8 cm) and 0-2 cm H_2O gauges are used for the dilution lines. The purpose of these latter gauges is to provide a check against possible back pressure developing in these lines which would affect the dilution ratios.

The flame ionization detector (FID) is used to determine the time at which the Main Line concentration has reached equilibrium and to monitor the concentration level during breakthrough studies and sample collection.

Breakthrough Studies

Low Relative Humidity (Dry Air)

For the measurement of sorbent tube capacity for a given vapor (breakthrough), six sorbent tubes containing only the 100 mg "front half" section of sorbent are connected in parallel to the 2S dilution line and to a 0.635-cm (1/4 in.) O.D. stainless steel six-port manifold. Flow through the manifold is controlled by a CFO and is established using a Metal Bellows Corporation Model MB41 pump. Flow through the orifice was measured as 1.14 liters per minute providing a 0.19-liter per minute flow to each of the tubes. (A separate set of orifice allows a similar determination at a flow rate of 1.0 liter per minute through each tube.) Equal flow through each of the tubes is insured by carefully selecting and/or adjusting packing in the tubes to have an equal pressure drop when precalibrated at a 0.2-liter per minute flow rate.

Once a steady state vapor concentration is established, the 2S concentration level is used to set the 100% point on the hydrocarbon analyzer. Then the valve is switched, and the flow from the breakthrough manifold is passed through the hydrocarbon analyzer and monitored either until 5% of the 2S level is observed or for a period of four hours--whichever occurs first.

High Relative Humidity

For the generation of a high relative humidity atmosphere, at least 80% R.H., water vapor is delivered into the generator Main Line via one of the side arms as shown in Figure F-2. A peristaltic pump, Cole-Parmer Masterflex, Model No. 7013, is used to deliver water into a heated copper coil (1/8 in. x 10 ft) contained in a tube furnace; the furnace temperature is maintained above 110°C and monitored by a thermocouple and optical pyrometer. Water is delivered at the rate of 1.9 g per minute to blend with the analyte-containing dry air stream flowing at a rate of 0.100 cu m per minute to produce an atmosphere of at least 80% R.H. at 25°C and 760 mm Hg.

All other aspects of the breakthrough test procedure are as described above.

Procedure

The overall procedure for a given sample is as follows:

1. Line air flow and dilution ratios are verified.

2. Sample delivery rate is determined by appropriate calibration.

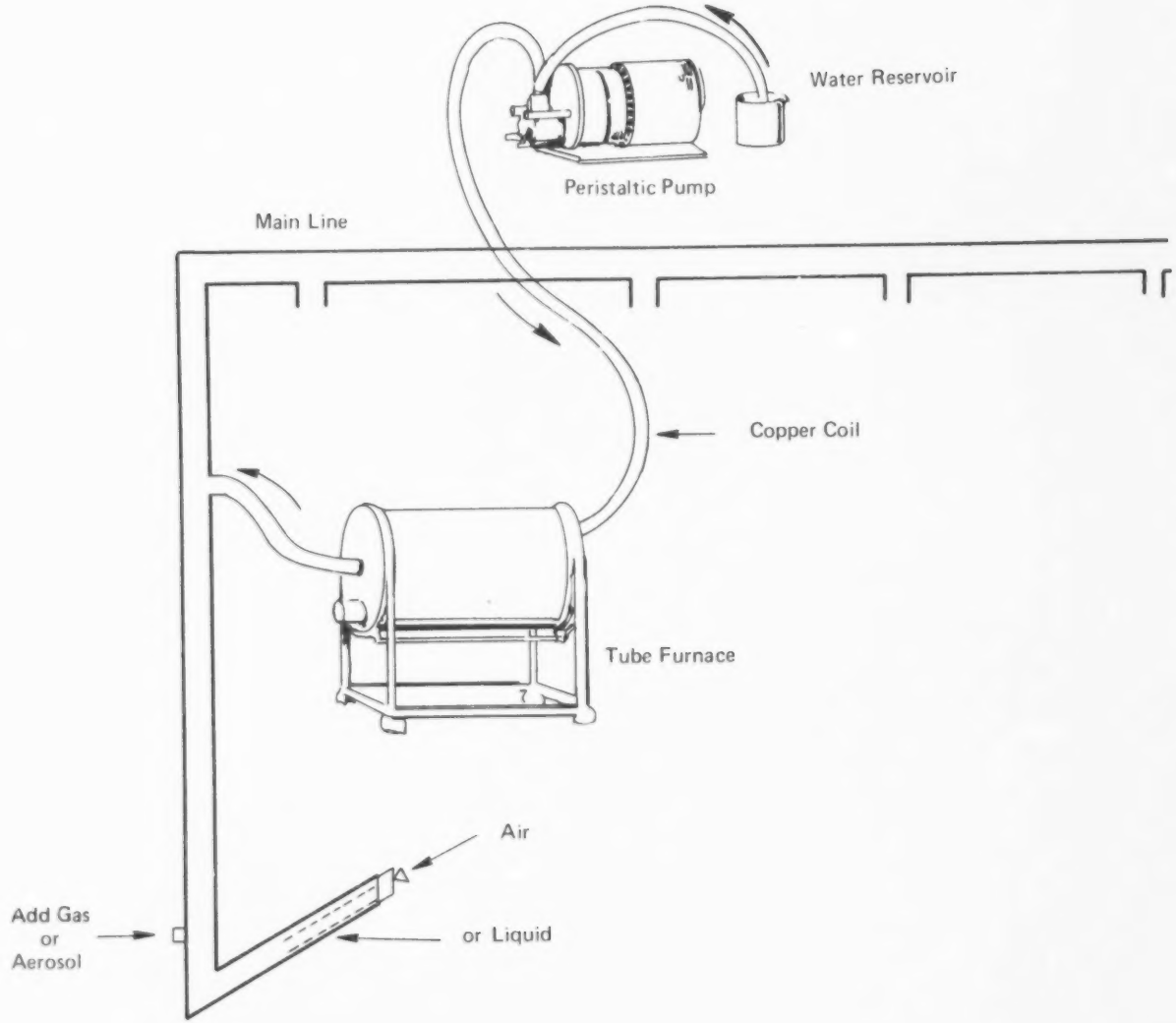

FIGURE F-2. Generation of High Humidity Atmospheres

3. Sample is fed into Main Line until vapor concentration equilibrium is established.

4. The breakthrough experiment is performed and subsequent sample collection volumes adjusted if necessary.

5. The four sets of six samples from the three concentration levels are collected simultaneously.

APPENDIX G. FIELD DATA

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830725	165424	*	.25	.41	2.60	5.36	3.83	14.43	.10	.16	.60	.9998
830725	171916	*	.21	.41	9.80	6.78	4.05	14.22	.02	.04	.50	.9998
830725	172120	*	.21	.42	3.60				.06	.12	.49	*
830725	172219	*	.20	.43	4.00				.05	.11	.46	*
830725	172954	*	.20	.33					*	*	.60	*
830725	173433	*	.21	.40	6.10				.03	.07	.53	*
830725	173706	*	.20	1.96	5.40				.04	.36	.10	*
830725	174824	*				9.72	4.11	14.28	*	*	*	.9997
830725	174931	*	.21	2.09	5.30				.04	.39	.10	*
830725	175153	*	.20	2.07	5.20				.04	.40	.10	*
830725	180000		1.98	1.80	4.60				.43	.39	1.10	*
830725	181500		2.04	1.31	4.40	11.49	4.18	14.20	.46	.30	1.56	.9997
830725	183000		1.98	1.26	3.90				.51	.32	1.57	*
830725	184501		2.06			11.89	3.98	14.57	*	*	*	.9997
830725	190000		1.99	.75	3.90				.51	.19	2.67	*
830725	191502		2.02	.33	3.30	11.51	3.88	14.72	.61	.10	6.16	.9997
830725	193001		1.93	.39	5.50				.35	.07	4.94	*
830725	194502		2.00	.50	2.80	11.47	4.19	14.23	.71	.18	3.99	.9997
830725	200001		1.94	.58	2.40				.81	.24	3.35	*
830725	201500		2.00	.73	2.50	11.19	4.10	13.96	.80	.29	2.73	.9997
830725	203002		1.94	.99	-7.30				-.27	-.13	1.97	*
830725	204501		2.00	.68	2.80	11.09	4.52	13.32	.71	.24	2.92	.9997
830725	210001		1.95	.74	11.20				.17	.07	2.64	*
830725	211501		2.00	.76	3.00	9.99	3.94	14.08	.67	.25	2.63	.9997
830725	213002		1.93	.79	-.10				-19.30	-7.89	2.45	*
830725	214200	SPAN 402				10.44	3.92	14.17	*	*	*	.9997
830725	214240	*	1.99	1.07	*17.5				*	*	1.87	*
830725	214300	ZERO 402							*	*	*	*
830725	214317	*	1.98	1.05	*-0.4				*	*	1.89	*
830725	214400	ZERO HNU							*	*	*	*
830725	214414	*	1.90	*.00	2.70				.70	*	*	*
830725	214502	*	1.98	.78	2.60				.76	.30	2.52	*
830725	214700	SPAN HNU							*	*	*	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830725	214747	*	1.91	*20.0	3.80				.50	*	*	*
830725	220002		1.90	.28	2.30				.83	.12	6.88	*
830725	221500		1.96	.29	2.50				.78	.12	6.77	*
830725	223001		1.91	.79	2.70				.71	.29	2.43	*
830725	224500		1.95	.78	2.40				.81	.32	2.51	*
830725	230002		1.90	.78	2.70				.70	.29	2.43	*
830725	231500		1.95	.67	2.50				.78	.27	2.93	*
830725	233001		1.90	.88	2.30				.83	.38	2.15	*
830725	234500		1.95	.56	2.30				.85	.24	3.47	*
830726	1		1.90	.25	2.50				.76	.10	7.58	*
830726	1502		1.95	.66	3.60				.54	.18	2.96	*
830726	3000		1.90	.67	4.10				.46	.16	2.83	*
830726	4500		1.96	.68	4.90				.40	.14	2.88	*
830726	10001		1.89	.70	5.10				.37	.14	2.72	*
830726	11500		1.95	.69	5.40				.36	.13	2.81	*
830726	13001		1.89	.69	6.60				.29	.10	2.75	*
830726	14500		1.96	.69	5.60				.35	.12	2.83	*
830726	20000		1.89	.71	5.80				.33	.12	2.67	*
830726	21502		1.94	.72	6.50				.30	.11	2.71	*
830726	23001		1.90	.73	7.60				.25	.10	2.59	*
830726	24501		1.95	.74	7.00				.28	.11	2.64	*
830726	30001		1.89	.76	6.90				.27	.11	2.48	*
830726	31500		1.96	.74	6.70				.29	.11	2.65	*
830726	33000		1.89	.75	6.40				.30	.12	2.53	*
830726	34502		1.94	.75	5.90				.33	.13	2.59	*
830726	40002		1.90	.75	5.90				.32	.13	2.55	*
830726	41502		1.94	.76	9.50				.20	.08	2.55	*
830726	43002		1.89	.79	6.00				.32	.13	2.39	*
830726	44502		1.95	.75	6.30				.31	.12	2.61	*
830726	50000		1.89	.77	6.10				.31	.13	2.46	*
830726	51500		1.95	.76	5.40				.36	.14	2.55	*
830726	53000		1.89	.77	6.00				.32	.13	2.46	*
830726	54501		1.95	.79	6.30				.31	.13	2.47	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830726	60001		1.89	.79	5.50				.34	.14	2.38	*
830726	61501		1.94	.77	7.70				.25	.10	2.53	*
830726	63002		1.89	.82	5.40				.35	.15	2.32	*
830726	64502		1.94	.76	4.80				.40	.16	2.54	*
830726	70000		1.89	.78	4.30				.44	.18	2.44	*
830726	71500		1.94	.76	5.40				.36	.14	2.55	*
830726	73001		1.90	.78	4.20				.45	.19	2.44	*
830726	74100	SPAN 402							*	*	*	*
830726	74102	*	1.95	.83	*17.3				*	*	2.36	*
830726	74130	ZERO 402							*	*	*	*
830726	74158	*	1.90	.93	*-1.0				*	*	2.04	*
830726	74501	*	1.95	*18.9	3.70				.53	*	*	*
830726	74600	SPAN HNU							*	*	*	*
830726	74620	*	1.90	*19.4	3.60				.53	*	*	*
830726	74700	ZERO HNU							*	*	*	*
830726	74708	*	1.94	*.01	3.60				.54	*	*	*
830726	80000	*	1.89	.08	3.60				.53	.02	24.62	*
830726	81500	*	1.96	.08	3.80				.52	.02	25.70	*
830726	83000	*	1.90	.08	8.20				.23	.01	24.75	*
830726	84500		1.94	.53	15.00				.13	.04	3.67	*
830726	90002		1.89	.55	14.30				.13	.04	3.44	*
830726	91501		1.95	.59	13.10				.15	.04	3.32	*
830726	93001		1.90	.54	12.10				.16	.04	3.52	*
830726	94501		1.95	.55	11.80				.17	.05	3.56	*
830726	100001		1.91	.54	9.60				.20	.06	3.52	*
830726	101501		1.96	.54	9.10				.22	.06	3.64	*
830726	103000		1.90	.55	7.90				.24	.07	3.47	*
830726	104500		1.95	.55	7.40				.26	.07	3.55	*
830726	110002		1.90	.57	6.70				.28	.08	3.34	*
830726	111501		1.94	.56	6.30				.31	.09	3.44	*
830726	113000		1.91	.56	6.20				.31	.09	3.41	*
830726	114502		1.96	.56	5.60				.35	.10	3.48	*
830726	120002		1.91	.57	5.50				.35	.10	3.36	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830726	121501		1.96	.56	5.80				.34	.10	3.47	*
830726	121700	ZERO 402							*	*	*	*
830726	121729	*	1.96	.57	*-.5				*	*	3.44	*
830726	121800	SPAN 402							*	*	*	*
830726	121858	*	1.98	1.00	*16.8				*	*	1.98	*
830726	121900	ZERO HNU							*	*	*	*
830726	121954	*	1.91	*.00	6.90				.28	*	*	*
830726	122100	SPAN HNU							*	*	*	*
830726	122110	*	1.96	*20.1	4.10				.48	*	*	*
830726	123000	*							*	*	*	*
830726	123002		1.91	.57	5.80				.33	.10	3.36	*
830726	124501		1.96	.56	5.60				.35	.10	3.51	*
830726	130000		1.91	.57	5.00				.38	.11	3.38	*
830726	131502		2.86	.57	5.10				.56	.11	5.03	*
830726	133000		.91	.58	4.40				.21	.13	1.56	*
830726	134501		1.14	.59	4.60				.25	.13	1.91	*
830726	140000		1.19	.59	4.10				.29	.14	2.01	*
830726	141501		1.18	.61	3.80				.31	.16	1.94	*
830726	143000		1.21	.60	3.70				.33	.16	2.01	*
830726	144500		1.24	.60	3.80				.33	.16	2.07	*
830726	150001		1.23	.62	3.70				.33	.17	1.98	*
830726	151500		1.24	.61	3.90				.32	.16	2.01	*
830726	153000		3.68	.63	4.10				.90	.15	5.81	*
830726	154500		3.43	.65	4.20				.82	.15	5.29	*
830726	160000		3.49	.65	4.00				.87	.16	5.35	*
830726	160205		1.70	.66	4.20				.41	.16	2.58	*
830726	160300	SPAN CSI							*	*	*	*
830726	160318	*	*17.6	.66	4.20				*	.16	*	*
830726	160500	ZERO CSI							*	*	*	*
830726	160548	*	*.02	.66	4.10				*	.16	*	*
830726	161004	*	2.26	.66	6.60				.34	.10	3.42	*
830726	161345	*	1.74	.66	4.00				.44	.16	2.65	*
830726	161428	*	1.83	.66	4.00				.46	.16	2.78	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830726	161501	*	1.69	.66	4.00				.42	.16	2.56	*
830726	163000	*	2.06	1.99	3.30				.62	.60	1.03	*
830726	163500	SPAN HNU CSI							*	*	*	*
830726	163521	*	*21.0	*20.0	3.40				*	*	*	*
830726	163752	*	3.43	2.00	3.40				1.01	.59	1.72	*
830726	164200	SPAN HNU CSI							*	*	*	*
830726	164249	*	*17.1	*20.0	3.20				*	*	*	*
830726	164501	*	4.62	.68	5.00				.92	.14	6.80	*
830726	170000	*	1.40	.64	4.40				.32	.15	2.18	*
830726	171501		1.08	.64	4.40				.25	.14	1.69	*
830726	173002		.99	.66	4.10	11.66			.24	.16	1.51	*
830726	174500		.94	.66	4.20				.22	.16	1.43	*
830726	180001		.99	.66	7.40	13.02			.13	.09	1.51	*
830726	181502		.92	.65	4.10				.22	.16	1.40	*
830726	183000		.96	.66	4.20	13.82			.23	.16	1.46	*
830726	184500		.93	.65	3.80				.25	.17	1.43	*
830726	190001		.92	.64	7.40	14.18			.12	.09	1.43	*
830726	191502		.92	.63	4.10				.23	.15	1.45	*
830726	193000		.90	.63	4.10	10.00			.22	.15	1.42	*
830726	194501		.82	.64	3.90				.21	.16	1.29	*
830726	200002		.76	.62	7.30	10.35			.10	.09	1.21	*
830726	201502		.85	.61	3.60				.24	.17	1.40	*
830726	203000		.90	.58	3.50	10.56			.26	.17	1.55	*
830726	204500		.82	.58	3.60				.23	.16	1.41	*
830726	210000		.77	.57	3.50	10.52			.22	.16	1.35	*
830726	211500		.50	.56	4.00				.13	.14	.89	*
830726	213002		.70	.57	3.60	10.64			.19	.16	1.24	*
830726	214500		.93	.55	3.70				.25	.15	1.68	*
830726	220001		.72	.54	4.10	10.67			.18	.13	1.34	*
830726	221502		.69	.53	5.00				.14	.11	1.31	*
830726	223001		.54	.52	7.40	10.59			.07	.07	1.03	*
830726	224501		.71	.53	5.20				.14	.10	1.35	*
830726	230001		.70	.55	7.50	10.52			.09	.07	1.27	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830726	231501		.47	.52	5.70				.08	.09	.90	*
830726	233002		.55	.55	5.80	10.31			.10	.09	1.01	*
830726	234500		.48	.52	5.80				.08	.09	.93	*
830727	1		.62	.55	5.60	10.23			.11	.10	1.13	*
830727	1501		.52	.51	6.00				.09	.09	1.01	*
830727	3002		.59	.51	4.10	10.44			.14	.13	1.14	*
830727	4500		.26	.51	5.80				.05	.09	.52	*
830727	10000	FAILURE							*	*	*	*
830727	21502	*	6.81	31.19	3.10				2.20	10.06	.22	*
830727	23001	*	6.88	31.19	3.10	11.68			2.22	10.06	.22	*
830727	24500	*	6.85	31.35	3.10				2.21	10.11	.22	*
830727	30002	*	6.69	31.20	3.10	11.88			2.16	10.06	.21	*
830727	31502	*	6.72	31.34	3.10				2.17	10.11	.21	*
830727	33000	FAILURE							*	*	*	*
830727	72830	RESTART							*	*	*	*
830727	72830	*	.07	.53	6.50	10.83			.01	.08	.13	*
830727	72944	*	.07	.50	6.60				.01	.08	.14	*
830727	73045	*	.73	.52	6.50				.11	.08	1.40	*
830727	73300	SPAN 402							*	*	*	*
830727	73327	*	.84	.51	*17.5				*	*	1.64	*
830727	73400	ZERO 402							*	*	*	*
830727	73413	*	.76	1.01	*-0.9				*	*	.75	*
830727	73800	SPAN HNU CSI							*	*	*	*
830727	73815	*	*19.5	*19.2	6.40				*	*	*	*
830727	73851	*	1.66	1.92	6.40				.26	.30	.86	*
830727	74018	*	1.67	.02	6.50				.26	*	83.60	*
830727	74200	SPAN HNU							*	*	*	*
830727	74224	*	1.67	.60	6.40				.26	.09	2.78	*
830727	75300	*							*	*	*	*
830727	75357	*	4.30	.55	23.20				.19	.02	7.83	*
830727	75900	*							*	*	*	*
830727	75927	*	1.45	.13	9.10	10.78			.16	.01	11.21	*
830727	82600	*							*	*	*	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830727	82611	*	.08	3.82	6.70	10.17			.01	.57	.02	*
830727	83400	*							*	*	*	*
830727	83445	*	-.03		32.10				*	*	-16.37	*
830727	83500	ZERO HNU	*.00	*.00					*	*	*	*
830727	83538	*	*.00	*.00	30.80				*	*	*	*
830727	83800	SPAN 402							*	*	-.03	*
830727	83813	*	-.11	3.82	*17.1				*	*	*	*
830727	83900	ZERO 402							*	*	-.19	*
830727	83912	*	-.65	3.48	*-0.9				*	*	*	*
830727	84300	SPAN CSI							*	*	*	*
830727	84337	*	*19.5	4.51	*16.7				*	*	*	*
830727	84800	ZERO CSI							*	.02	*	*
830727	84856	*	*0.20	.43	18.20				.13	.27	.46	*
830727	85100		2.02	4.35	16.00				.10	.23	.43	*
830727	90001		1.78	4.14	17.80	10.53			*	*	*	*
830727	92100								.47	.14	3.28	*
830727	92158		4.59	1.40	9.80				.21	.14	1.48	*
830727	92258		1.89	1.28	9.10				.24	.13	1.90	*
830727	93002		1.83	.96	7.50				.17	.10	1.74	*
830727	94537		1.40	.80	8.00				.17	.09	1.95	*
830727	100002		1.49	.76	8.80	9.94			.35	.10	3.35	*
830727	103001		2.25	.67	6.50	9.74			.22	.10	2.12	*
830727	110001		1.58	.75	7.20	9.52			.25	.16	1.57	*
830727	110301		1.12	.71	4.40				.22	.18	1.28	*
830727	120001		.90	.70	4.00	10.88			.15	.12	1.27	*
830727	123001		.85	.67	5.80	13.54			.20	.20	.99	*
830727	130000		.79	.80	4.00	7.53			.23	.25	.94	*
830727	133001		.76	.81	3.30	7.09			.26	.26	1.00	*
830727	140000		.79	.78	3.00	8.46			.19	.19	1.03	*
830727	143000		.67	.66	3.50	7.05			*	*	*	*
830727	144300	SPAN 402							*	*	.94	*
830727	144336	*	.67	.71	*15.5				*	*	*	*
830727	144400	ZERO 402										

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830727	144449	*	.76	.71	*0.0				*	*	1.08	*
830727	144700	SPAN HNU							*	*	*	*
830727	144740	*	*26.8	*23.5	3.90				*	*	*	*
830727	144800	ZERO HNU							*	*	*	*
830727	144858	*	.59	*.01	3.70				.16	*	*	*
830727	145700	SPAN CSI							*	*	*	*
830727	145716	*	*18.8	*19.8	3.50				*	*	*	*
830727	145800	ZERO CSI							*	*	*	*
830727	145859	*	*-.21	.90	3.30				*	.27	*	*
830727	150000	*	.11	.83	3.50	6.12			.03	.24	.13	*
830727	153000	*							*	*	*	*
830727	153000		.63	.65	3.20	4.97			.20	.20	.97	*
830727	160002		.57	.62	2.80	15.96			.20	.22	.92	*
830727	163001			.61	2.80	24.74			*	.22	*	*
830727	170002		1.45	.61	2.70	22.17			.54	.23	2.38	*
830727	173002		.51	.58	2.70	22.31			.19	.22	.88	*
830727	180002		.67	.60	2.80	13.53			.24	.21	1.13	*
830727	183001		1.80	.60	3.40	6.44			.53	.18	3.01	*
830727	190000		1.39	.58	3.10	9.05			.45	.19	2.40	*
830727	193000		.63	.56	2.70	5.60			.23	.21	1.13	*
830727	200002		.46	.54	2.50	8.18			.19	.22	.85	*
830727	203001		.34	.51	2.40	10.23			.14	.21	.67	*
830727	210002		.54	.50	2.10	11.88			.26	.24	1.08	*
830727	213001		.46	.48	2.30	13.36			.20	.21	.96	*
830727	220000		.36	.45	2.60	13.59			.14	.17	.81	*
830727	223002		.52	.23	2.70	13.07			.19	.09	2.27	*
830727	230001		.63	.19	2.80	13.48			.22	.07	3.31	*
830727	233000		.59	.19	3.00	13.92			.20	.06	3.02	*
830728	1		.55	.19	3.40	14.08			.16	.05	2.96	*
830728	3002		.63	.19	3.40	13.98			.19	.05	3.40	*
830728	10000		1.07	.19	4.10	14.59			.26	.05	5.61	*
830728	13001		.77	.18	4.10	14.43			.19	.05	4.18	*
830728	20002		1.04	.16	4.70	13.46			.22	.03	6.33	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830728	23000		1.08	.16	4.60	13.32			.23	.04	6.58	*
830728	30002		.99	.15	4.50	12.75			.22	.03	6.66	*
830728	33000		.68	.15	4.40	12.65			.15	.03	4.61	*
830728	40001		.71	.14	4.80	12.45			.15	.03	5.14	*
830728	43000		.16	.14	4.60	12.50			.03	.03	1.13	*
830728	50001		.20	.14	4.40	12.34			.05	.03	1.46	*
830728	53002		.70	.12	4.00	12.06			.17	.03	5.85	*
830728	60002		.57	.12	3.70	12.09			.15	.03	4.67	*
830728	63001		2.34	.12	3.40	11.96			.69	.04	19.60	*
830728	70002		.67	.09	2.80	12.15			.24	.03	7.07	*
830728	73001		2.18	.49	4.30	12.97			.51	.11	4.45	*
830728	80001		.68	1.67	2.50	12.30			.27	.67	.41	*
830728	81400	SPAN 402							*	*	*	*
830728	81422	*	.78	1.13	*17.5				*	*	.70	*
830728	81500	ZERO 402							*	*	*	*
830728	81510	*	.57	1.09	*-.7				*	*	.53	*
830728	81600	ZERO HNU							*	*	*	*
830728	81608	*	.50	*.01	3.00				.17	*	*	*
830728	81800	SPAN HNU							*	*	*	*
830728	81851	*	.22	*19.9	3.20				.07	*	*	*
830728	82700	SPAN CSI							*	*	*	*
830728	82709	*	*22.4	.83	3.20				*	.26	*	*
830728	82800	*							*	*	*	*
830728	82819	*	2.27	.82	3.14				*	*	2.76	*
830728	83002	*	2.96	.81	3.00	12.63			.99	.27	3.67	*
830728	83226	*	3.21	.81	2.90				1.11	.28	3.94	*
830728	83500	*							*	*	*	*
830728	83522	*	-.21	.76	3.00				-.07	.25	-.28	*
830728	90001		.49	.51	2.60	12.55			.19	.20	.96	*
830728	93001		.58	.40	2.80	12.59			.21	.14	1.47	*
830728	100001		.65	.33	3.40	15.41			.19	.10	1.97	*
830728	101927		.11	.31	3.60				.03	.09	.35	*
830728	103002		.37	.33	5.00	11.92			.07	.07	1.10	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830728	104407		1.73	.33	5.00				.35	.07	5.23	*
830728	110001		.17	.33	5.30	8.63			.03	.06	.51	*
830728	113001		1.18	.29	5.50	6.26			.21	.05	4.04	*
830728	115717		.82	.25	6.10	8.25			.13	.04	3.29	*
830728	121402		.38	.27	5.90				.06	.05	1.41	*
830728	123000		.96	.26	5.30	12.58			.18	.05	3.67	*
830728	124402		.44	.26	5.40				.08	.05	1.72	*
830728	130001		.67	.26	5.20	13.71			.13	.05	2.56	*
830728	131402		.70	.26	-7.40				-.09	-.04	2.65	*
830728	133001		1.18	.30	5.20	12.47			.23	.06	3.91	*
830728	134401		1.82	.26	5.00				.36	.05	6.95	*
830728	140001		1.50	.25	6.10	9.74			.25	.04	5.99	*
830728	141402		.26	.25	5.60				.05	.05	1.04	*
830728	143000		.61	.27	4.70	13.80			.13	.06	2.25	*
830728	144401		.46	.25	4.90				.09	.05	1.81	*
830728	150001		.45	.26	5.00	14.70			.09	.05	1.73	*
830728	151400		.58	.30	5.20				.11	.06	1.93	*
830728	153000		.74	.35	5.70	15.37			.13	.06	2.10	*
830728	154400		3.65	2.34	11.10				.33	.21	1.56	*
830728	160001		1.45	.96	7.60				.19	.13	1.51	*
830728	161401		.86	.52	6.20				.14	.08	1.65	*
830728	163002		.65	.36	5.00				.13	.07	1.81	*
830728	164400		.64	.34	6.00				.11	.06	1.85	*
830728	170001		.61	.30	6.50				.09	.05	2.02	*
830728	171402		4.59	4.90	14.70				.31	.33	.94	*
830728	173001		2.76	1.75	6.00				.46	.29	1.58	*
830728	180002		1.08	.78	2.00				.54	.39	1.38	*
830728	183001		.67	.55	2.00				.34	.27	1.23	*
830728	190000		.64	.49	3.50				.18	.14	1.32	*
830728	193002		.56	.44	4.00				.14	.11	1.26	*
830728	200001		.49	.49	5.00				.10	.10	.99	*
830728	203000		.47	.49	6.00				.08	.08	.94	*
830728	210001		.85	.63	6.50				.13	.10	1.37	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830728	213000		.86	.57	6.00				.14	.10	1.51	*
830728	220001		.54	.54	6.50				.08	.08	1.00	*
830728	223001		.33	.49	9.50				.04	.05	.68	*
830728	230001		.46	.47	6.50				.07	.07	.99	*
830728	233000		.60	.47	4.50				.13	.10	1.28	*
830729	2		.46	.44	2.00				.23	.22	1.04	*
830729	3000		.47	.38	3.50				.14	.11	1.23	*
830729	10000		.48	.40	1.50				.32	.26	1.21	*
830729	13001		.46	.35	2.50				.18	.14	1.32	*
830729	20000		.39	.37	2.00				.19	.19	1.04	*
830729	23000		.38	.37	1.00				.38	.37	1.03	*
830729	30000		.38	.37	1.50				.26	.25	1.03	*
830729	33001		.38	.35	.50				.75	.70	1.07	*
830729	40001		.35	.35	2.00				.18	.17	1.01	*
830729	43000		.34	.36	1.50				.23	.24	.95	*
830729	50001		.30	.36	2.00				.15	.18	.82	*
830729	53001		.24	.38	5.50				.04	.07	.62	*
830729	60001		1.19	.37	4.50				.26	.08	3.22	*
830729	63002		.48	.36	5.50				.09	.07	1.34	*
830729	70001		.19	.37	6.00				.03	.06	.52	*
830729	73002		.24	1.50	7.00				.03	.21	.16	*
830729	73200	SPAN HNU							*	*	*	*
830729	73229	*	1.18	*16.7	3.00				.39	*	*	*
830729	73300	ZERO HNU							*	*	*	*
830729	73308	*	2.83	*0.04	5.00				.57	*	*	*
830729	73800	SPAN CSI							*	*	*	*
830729	73824	*	*24.7	.40	4.50				*	.09	*	*
830729	74000	ZERO CSI							*	*	*	*
830729	74059	*	*-.7	.40	*0.0				*	*	*	*
830729	74300	*							*	*	*	*
830729	91402		.45	3.16	3.50				.13	.90	.14	*
830729	93001		.59	3.25	4.00				.15	.81	.18	*
830729	93201		.49	3.26	4.50				.11	.72	.15	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	93401		.49	3.20	4.00				.12	.80	.15	*
830729	93601		.47	2.66	4.00				.12	.66	.18	*
830729	93801		.53	2.57	4.50				.12	.57	.21	*
830729	94002		.50	2.46	5.00				.10	.49	.21	*
830729	94202		.50	2.36	4.00				.13	.59	.21	*
830729	94402		.52	2.34	4.50				.12	.52	.22	*
830729	94602		.51	2.26	4.00				.13	.56	.23	*
830729	94802		.54	2.20	4.00				.13	.55	.24	*
830729	95000		.51	2.18	4.00				.13	.55	.23	*
830729	95200		.54	2.10	4.50				.12	.47	.26	*
830729	95400		.54	2.22	4.00				.14	.55	.24	*
830729	95601		.55	2.26	4.50				.12	.50	.25	*
830729	95801		.53	2.16	4.50				.12	.48	.25	*
830729	100001		.55	1.81	5.00				.11	.36	.30	*
830729	100202		.55	1.80	4.50				.12	.40	.31	*
830729	100400		.61	1.88	5.50				.11	.34	.33	*
830729	100600		.51	1.72	5.00				.10	.34	.29	*
830729	100800		.79	1.66	3.00				.26	.55	.47	*
830729	101001		.66	1.48	3.50				.19	.42	.45	*
830729	101200		.80	1.42	3.50				.23	.41	.57	*
830729	101401		.75	1.30	2.00				.38	.65	.58	*
830729	101600		.78	1.24	3.50				.22	.36	.62	*
830729	101802		.79	1.14	3.50				.22	.33	.69	*
830729	102000		.79	1.00	4.50				.17	.22	.78	*
830729	102202		.81	.96	3.50				.23	.27	.85	*
830729	102401		.77	.90	3.00				.26	.30	.85	*
830729	102600		.71	.95	2.50				.28	.38	.75	*
830729	102802		.67	.80	6.00				.11	.13	.83	*
830729	103001		.69	.84	4.00				.17	.21	.82	*
830729	103200		.71	.74	4.00	67.00	6.80	11.90	.18	.19	.96	.9990
830729	103401		.69	.74	4.50	17.00	6.80	11.80	.15	.16	.94	.9997
830729	103600		.69	.71	3.50	13.00	7.00	11.70	.20	.20	.98	.9998
830729	103802		.63	.70	2.00	11.00	6.80	11.90	.32	.35	.91	.9998

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY	
830729	104001		.52	.68	3.50	9.00	6.80	12.00	.15	.19	.77	.9998	
830729	104200		.55	.65	4.00	8.00	7.00	11.90	.14	.16	.84	.9998	
830729	104402		.58	.63	5.50	8.00	6.80	11.90	.11	.11	.93	.9998	
830729	104601		.57	.63	4.00	8.00	6.80	12.00	.14	.16	.91	.9998	
830729	104802		.60	.62	3.50	8.00	6.80	12.00	.17	.18	.97	.9998	
830729	105001		.61	.61	3.50				.17	.17	.99		*
830729	105200		.63	.60	3.00	7.50	6.80	12.00	.21	.20	1.05	.9998	
830729	105402		.55	.61	2.50	7.50	6.70	12.10	.22	.24	.91	.9998	
830729	105601		.54	.61	2.00	7.50	6.70	11.90	.27	.30	.89	.9998	
830729	105800		.43	.61	3.00	7.00	6.80	11.90	.14	.20	.71	.9998	
830729	110001		.50	.61	3.00	7.00	6.70	12.10	.17	.20	.83	.9998	
830729	110200		.54	.60	3.50	7.00	6.70	12.00	.16	.17	.90	.9998	
830729	110402		.50	.60	5.00	6.50	6.70	12.10	.10	.12	.83	.9999	
830729	110601		.53	.62	4.50	6.50	6.70	12.10	.12	.14	.86	.9999	
830729	110800		.67	.59	2.50	7.00	6.60	12.20	.27	.23	1.14	.9998	
830729	111002		.45	.59	3.00	6.00	6.60	12.00	.15	.20	.77	.9999	
830729	111201		.44	.59	2.50	6.00	6.50	12.30	.18	.24	.75	.9999	
830729	111402		.44	.59	3.50	6.00	6.60	12.10	.13	.17	.74	.9999	
830729	111601		.47	.59	3.50	6.00	6.70	12.20	.13	.17	.80	.9999	
830729	111800		.46	.59	3.00	6.00	6.60	12.10	.15	.20	.77	.9999	
830729	112002		.49	.53	3.00	5.50	6.80	12.10	.16	.18	.91	.9999	
830729	112201		.45	.54	3.50	5.50	6.80	12.10	.13	.15	.83	.9999	
830729	112400		.52	.55	2.50	5.00	6.60	12.10	.21	.22	.96	.9999	
830729	112601		.54	.56	3.50	5.00	6.80	12.00	.15	.16	.96	.9999	
830729	112800		.59	.56	4.00	5.00	6.80	12.00	.15	.14	1.04	.9999	
830729	113002		.61	.57	3.50	5.00	6.80	12.00	.17	.16	1.07	.9999	
830729	113201		.67	.57	3.00	5.00	6.90	11.90	.22	.19	1.17	.9999	
830729	113400		.77	.56	2.50	5.00	7.00	11.80	.31	.23	1.37	.9999	
830729	113601		.78	.58	3.00	4.50	6.60	12.20	.26	.19	1.35	.9999	
830729	113800		.75	.58	3.50	4.50	6.60	12.20	.21	.16	1.30	.9999	
830729	114002		.67	.58	4.50	4.50	6.80	12.00	.15	.13	1.16	.9999	
830729	114201		.64	.58	3.50	4.50	6.80	12.00	.18	.17	1.09	.9999	
830729	114400		.61	.57	3.50	4.00	7.00	11.80	.17	.16	1.07	.9999	

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	114602		.63	.57	3.50				.18	.16	1.10	*
830729	114801		.66	.57	2.50	4.00	6.60	12.30	.27	.23	1.16	.9999
830729	115000		.72	.58	3.00	4.00	6.60	12.20	.24	.19	1.24	.9999
830729	115201		.73	.60	4.00	3.50	6.60	12.30	.18	.15	1.22	.9999
830729	115400		.87	.59	2.50	3.50	6.80	12.10	.35	.24	1.46	.9999
830729	115602		.80	.59	1.50	3.50	7.00	11.80	.53	.39	1.35	.9999
830729	115801		.69	.59	3.50	3.50	7.00	11.80	.20	.17	1.18	.9999
830729	120000		.68	.58	3.00	3.50	7.00	11.80	.23	.19	1.16	.9999
830729	120202		.68	.58	2.00	3.50	6.80	12.10	.34	.29	1.17	.9999
830729	120401		.71	.57	3.50	3.00	6.90	12.00	.20	.16	1.24	.9999
830729	120602		.75	.56	3.50	3.00	7.00	11.60	.21	.16	1.32	.9999
830729	120801		.68	.56	2.00	3.00	6.96	11.90	.34	.28	1.21	.9999
830729	121000		.62	.56	2.00		6.80	12.10	.31	.28	1.10	
830729	121201		.61	.56	2.00	3.00	7.40	11.00	.30	.28	1.09	.9999
830729	121400		.60	.56	2.50	3.00	7.00	11.60	.24	.22	1.08	.9999
830729	121602		.57	.56	2.00	3.00	7.00	11.90	.28	.28	1.01	.9999
830729	121800		.54	.56	3.00	3.00	6.90	12.00	.18	.19	.97	9999
830729	122002		.56	.56	2.00				.28	.28	1.01	*
830729	122200		.50	.55	2.00				.25	.27	.90	*
830729	122402		.53	.55	4.00				.13	.14	.95	*
830729	122600		.59	.56	2.00				.30	.28	1.05	*
830729	122802		.50	.56	3.50				.14	.16	.90	*
830729	123001		.48	.56	2.00	4.00	6.40	12.00	.24	.28	.86	.9999
830729	123202		.44	.56	2.00	2.00	6.70	12.10	.22	.28	.78	.9999
830729	123401		.48	.56	2.00	3.00	6.80	12.00	.24	.28	.85	.9999
830729	123600		.50	.56	2.00	2.00	6.90	12.00	.25	.28	.90	.9999
830729	123801		.51	.55	2.50	2.50	6.90	12.10	.21	.22	.94	.9999
830729	124000		.42	.56	2.50	2.50	7.00	11.60	.17	.22	.76	.9999
830729	124202		.46	.56	2.00	2.00	7.00	12.00	.23	.28	.83	.9999
830729	124400		.49	.56	2.00	2.00	6.40	12.60	.24	.28	.87	.9999
830729	124602		.54	.56	2.00	2.00	6.40	12.40	.27	.28	.97	.9999
830729	124801		.59	.56	2.00	2.50	6.80	12.30	.29	.28	1.05	.9999
830729	125000		.61	.57	2.50	3.00	7.02	11.90	.25	.23	1.08	.9999

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	125202		.63	.58	3.00	3.00	6.50	12.50	.21	.19	1.08	.9999
830729	125401		.67	.58	3.00	3.00	6.70	12.30	.22	.19	1.15	.9999
830729	125602		.69	.58	3.00	3.00	6.80	12.00	.23	.19	1.19	.9999
830729	125801		.68	.57	2.00	3.20	7.04	11.80	.34	.28	1.19	.9999
830729	130000		.63	.56	3.00	3.00	6.98	11.90	.21	.19	1.12	.9999
830729	130202		.33	.56	3.50	3.20	6.80	12.20	.10	.16	.59	.9999
830729	130401		.63	.56	3.00	3.50	6.96	12.00	.21	.19	1.12	.9999
830729	130600		.55	.56	2.50	4.00	7.04	11.80	.22	.23	.98	.9999
830729	130801		.56	.56	3.00	4.00	6.90	12.00	.19	.19	1.00	.9999
830729	131000		.60	.56	2.50	5.00	6.90	12.00	.24	.22	1.08	.9999
830729	131202		.54	.56	2.50	4.90	6.80	12.10	.22	.23	.96	.9999
830729	131400		.51	.56	2.00	5.00	6.96	12.00	.26	.28	.91	.9999
830729	131602		.53	.56	2.00	5.20	6.80	12.10	.27	.28	.95	.9999
830729	131801		.57	.55	2.00	6.00	7.00	11.80	.29	.27	1.04	.9999
830729	132002		.49	.55	2.00	6.50	7.30	11.50	.25	.28	.90	.9999
830729	132201		.49	.56	2.50	7.00	6.80	12.00	.20	.22	.88	.9998
830729	132400		.43	.56	2.50	7.00	6.90	12.10	.17	.22	.76	.9998
830729	132601		.53	.55	3.00	8.00	7.00	11.90	.18	.18	.96	.9998
830729	132800		.40	.59	2.00	8.50	7.00	11.90	.20	.29	.69	.9998
830729	133002		.36	.59	2.00	9.00	7.00	11.90	.18	.30	.61	.9998
830729	133201		.57	.58	2.00	10.00	7.10	11.80	.29	.29	.99	.9998
830729	133402		.53	.58	2.00	10.00	7.00	11.90	.27	.29	.91	.9998
830729	133601		.57	.58	2.50	11.00	7.40	11.40	.23	.23	.97	.9998
830729	133800		.57	.57	3.00	11.50	6.90	11.90	.19	.19	.99	.9998
830729	134002		.48	.57	2.00	12.00	6.90	12.00	.24	.29	.83	.9998
830729	134201		.57	.58	2.00	12.50	6.90	12.00	.28	.29	.99	.9998
830729	134402		.53	.58	2.50	13.00	6.80	11.90	.21	.23	.92	.9998
830729	134601		.50	.58	3.00	13.00	6.90	12.00	.17	.19	.87	.9998
830729	134800		.50	.59	2.00	14.00	7.60	11.00	.25	.29	.85	.9998
830729	135002		.45	.59	2.50	14.00	7.20	11.60	.18	.24	.77	.9998
830729	135200		.48	.58	2.00	14.00	7.20	11.50	.24	.29	.83	.9998
830729	135402		.47	.58	2.00	14.00	6.80	12.10	.23	.29	.80	.9997
830729	135601		.48	.57	2.00	14.50	6.80	12.00	.24	.29	.83	.9997

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	135800		.54	.56	2.50	14.50	7.20	11.50	.22	.22	.96	.9997
830729	140002		.52	.56	2.00				.26	.28	.92	*
830729	140200		.49	.57	2.50	2.50	6.80	12.00	.20	.23	.86	.9999
830729	140402		.48	.56	5.00	3.00	6.90	11.90	.10	.11	.86	.9999
830729	140601		.39	.56	2.00	3.00	7.00	11.60	.20	.28	.70	.9999
830729	140800	ZERO HNU			2.00				*	*	*	*
830729	140800	*	.79	*.00	7.00				.11	*	*	*
830729	140809	*	.79		5.00				.16	*	*	*
830729	141000	SPAN HNU			2.00				*	*	*	*
830729	141024	*	3.89	*16.6	6.00				.65	*	*	*
830729	141200	*	4.07	.61	4.50				.90	.14	6.62	*
830729	141300	SPAN CSI			2.00				*	*	*	*
830729	141340	*	*17.8	.56	3.00				*	.19	*	*
830729	141401	*	17.80	.56	3.50				5.09	.16	31.81	*
830729	141600	ZERO CSI			2.00				*	*	*	*
830729	141600	*	*.06	.55	2.00				*	.28	*	*
830729	141801	*		.56	4.50				*	.12	.01	*
830729	142000		.33	.56	3.00				.11	.19	.58	*
830729	142202		.33	.55	2.00				.16	.28	.59	*
830729	142401		.33	.55	3.00				.11	.18	.60	*
830729	142600		.33	.54	2.50	3.00	7.00	11.80	.13	.22	.61	.9999
830729	142801		.32	.54	2.00	3.00	7.10	11.90	.16	.27	.60	.9999
830729	143000		.32	.54	2.50				.13	.22	.60	*
830729	143201		.32	.54	2.50				.13	.22	.58	*
830729	143400		.31	.55	3.00	3.00	7.00	11.90	.10	.18	.57	.9999
830729	143601		.32	.55	3.00	3.00	6.90	11.90	.11	.18	.58	.9999
830729	143800		.36	.56	3.50	3.00	6.80	11.90	.10	.16	.64	.9999
830729	144002		.37	.56	3.00	3.00	6.90	12.00	.12	.19	.67	.9999
830729	144201		.38	.55	3.00	3.00	7.00	11.80	.13	.18	.68	.9999
830729	144400		.37	.56	4.50	3.00	6.90	11.90	.08	.12	.65	.9999
830729	144601		.36	.56	4.50	3.00	6.80	12.00	.08	.12	.65	.9999
830729	144800		.35	.56	4.50	3.00	7.00	11.60	.08	.12	.63	.9999
830729	145002		.36	.56	3.00	2.50	6.60	12.20	.12	.19	.64	.9999

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY	
830729	145201		.36	.57	4.50	3.00	6.70	12.10	.08	.13	.63	.9999	
830729	145400		.36	.57	4.00	3.00	6.80	12.00	.09	.14	.64	.9999	
830729	145601		.36	.57	4.00	3.00	6.90	11.90	.09	.14	.64	.9999	
830729	145800		.37	.60	3.50	3.00	7.00	11.70	.11	.17	.62	.9999	
830729	150002		.38	.59	3.50	3.00	7.00	11.80	.11	.17	.64	.9999	
830729	150201		.38	.60	4.00	3.00	7.00	11.80	.10	.15	.64	.9999	
830729	150400		.38	.59	5.00	3.00	7.00	11.80	.08	.12	.65	.9999	
830729	150602		.40	.59	4.00	3.00	7.00	11.90	.10	.15	.67	.9999	
830729	150801		.39	.60	3.50		7.00	11.90	.11	.17	.65		
830729	151000		.39	.60	3.00				.13	.20	.65		*
830729	151201		.37	.58	2.50				.15	.23	.64		*
830729	151400		.38	.58	4.50	3.00	7.10	11.80	.08	.13	.65	.9999	
830729	151600		.38	.58	3.50	3.00	6.80	11.80	.11	.16	.66	.9999	
830729	151801		.39	.58	3.50				.11	.16	.67		*
830729	152000		.41	.58	3.50	3.00	7.60	11.00	.12	.17	.71	.9999	
830729	152202		.43	.58	5.00	3.00	7.30	11.50	.09	.12	.75	.9999	
830729	152401		.43	.58	4.50	3.00	6.80	11.90	.10	.13	.74	.9999	
830729	152600		.43	.58	6.00	3.00	7.00	11.80	.07	.10	.75	.9999	
830729	152802		.43	.59	4.00	3.50	7.40	11.50	.11	.15	.73	.9999	
830729	153001		.41	.59	4.50	3.50	6.80	12.00	.09	.13	.69	.9999	
830729	153200		.40	.59	4.00	3.00	6.70	12.00	.10	.15	.67	.9999	
830729	153402		.39	.60	3.50	3.00	6.70	12.10	.11	.17	.65	.9999	
830729	153601		.41	.59	4.50	3.00	6.50	12.40	.09	.13	.68	.9999	
830729	153800		.40	.59	4.00				.10	.15	.69		*
830729	154002		.41	.60	4.50				.09	.13	.68		*
830729	154201		.42	.59	4.50				.09	.13	.70		*
830729	154400		.42	.60	4.50				.09	.13	.70		*
830729	154602		.42	.59	5.00				.08	.12	.72		*
830729	154801		.43	.59	3.50	3.50	6.60	12.20	.12	.17	.73	.9999	
830729	155000		.43	.59	5.50				.08	.11	.72		*
830729	155202		.41	.61	3.50				.12	.18	.66		*
830729	155401		.39	.63	3.50				.11	.18	.63		*
830729	155600		.40	.64	2.50	4.00	7.10	11.80	.16	.26	.63	.9999	

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY	
830729	155802		.40	.64	4.00	4.00	7.00	11.70	.10	.16	.62	.9999	
830729	160001		.38	.66	4.00	4.00	6.60	12.30	.10	.16	.58	.9999	
830729	160200		.37	.65	2.00	4.00	6.70	12.00	.19	.33	.57	.9999	
830729	160402		.37	.65	2.50	4.00	6.80	12.00	.15	.26	.58	.9999	
830729	160601		.39	.69	3.00	4.00	6.70	12.00	.13	.23	.57	.9999	
830729	160800		.39	.68	3.50	4.00	6.70	12.10	.11	.19	.58	.9999	
830729	161001		.39	.65	3.50				.11	.19	.60		*
830729	161200		.40	.63	3.00				.13	.21	.63		*
830729	161402		.39	.63	4.50				.09	.14	.62		*
830729	161601		.39	.63	4.00	4.00	6.80	12.00	.10	.16	.62	.9999	
830729	161800		.38	.62	2.50	4.00	6.80	11.90	.15	.25	.60	.9999	
830729	162002		.38	.63	4.50	4.00	6.80	12.00	.08	.14	.61	.9999	
830729	162201		.37	.62	4.00	4.00	6.70	12.00	.09	.15	.61	.9999	
830729	162400		.36	.61	3.50				.10	.17	.60		*
830729	162601		.37	.64	3.50	4.00	6.80	12.00	.10	.18	.57	.9999	
830729	162800		.39	.65	3.00				.13	.22	.60		*
830729	163002		.39	.64	3.50				.11	.18	.61		*
830729	163201				2.00				*	*	*		*
830729	163201		.75	.65	2.00				.37	.32	1.15		*
830729	163400		.72	.64	2.50				.29	.26	1.12		*
830729	163602		.72	.63	2.50				.29	.25	1.15		*
830729	163801		.69	.63	2.00				.35	.32	1.09		*
830729	164002		.63	.74	2.00				.31	.37	.85		*
830729	164201		.78	.64	2.00				.39	.32	1.22		*
830729	164400		.77	.63	2.50				.31	.25	1.22		*
830729	164602		.52	.62	3.00				.17	.21	.84		*
830729	164801		.64	.63	2.00	4.50	6.70	12.10	.32	.31	1.02	.9999	
830729	165000		.35	.63	2.00				.18	.32	.55		*
830729	165202		.51	.63	2.00	4.50	6.80	12.00	.26	.31	.82	.9999	
830729	165401		.64	.62	2.00	4.50	6.40	12.40	.32	.31	1.04	.9999	
830729	165600		.49	.63	2.50	4.50	6.90	11.90	.20	.25	.79	.9999	
830729	165801		.55	.63	2.00	5.00	7.10	11.50	.27	.31	.87	.9999	
830729	170000		.60	.62	2.00				.30	.31	.96		*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	170202		.49	.87	2.00				.25	.43	.57	*
830729	170401		1.12	2.47	5.50	3.00	6.80	12.00	.20	.45	.45	.9999
830729	170600		3.80	2.46	8.00				.48	.31	1.55	*
830729	170801		3.68	2.24	7.50	3.00	7.30	11.40	.49	.30	1.64	.9999
830729	171001		3.30	2.06	8.00	3.00	7.20	11.50	.41	.26	1.60	.9999
830729	171200		2.93	1.90	7.00				.42	.27	1.54	*
830729	171400		2.58	1.75	7.00				.37	.25	1.47	*
830729	171602		2.40	1.80	7.00				.34	.26	1.33	*
830729	171801		2.58	1.85	7.00	3.00	7.00	11.80	.37	.26	1.39	.9999
830729	172000		2.61	1.62	7.50				.35	.22	1.61	*
830729	172200		2.32	1.51	7.50	3.50	7.20	11.50	.31	.20	1.53	.9999
830729	172402		2.11	1.41	7.00	4.00	7.40	11.20	.30	.20	1.50	.9999
830729	172601		1.82	1.32	5.50	4.00	7.50	11.00	.33	.24	1.38	.9999
830729	172801		1.68	1.25	6.50				.26	.19	1.35	*
830729	173000		1.62	1.18	4.50	3.50	7.20	11.40	.36	.26	1.37	.9999
830729	173202		1.38	1.11	5.50	4.50	5.80	13.10	.25	.20	1.23	.9999
830729	173401		1.29	1.07	5.50	4.00	6.30	12.50	.23	.19	1.21	.9999
830729	173600		1.21	1.01	5.00				.24	.20	1.20	*
830729	173800		1.15	.98	5.00				.23	.20	1.17	*
830729	174001		1.02	.95	4.50				.23	.21	1.08	*
830729	174201		1.08	.92	4.50				.24	.20	1.17	*
830729	174400		1.02	.90	3.50	5.00	7.80	10.50	.29	.26	1.13	.9999
830729	174601		.66	.88	4.00				.17	.22	.75	*
830729	174801		.95	.84	4.50	5.00	7.60	11.50	.21	.19	1.13	.9999
830729	175000		.91	.80	5.00				.18	.16	1.14	*
830729	175201		.83	.80	2.50				.33	.32	1.04	*
830729	175400		.77	.79	4.50				.17	.18	.97	*
830729	175602		.72	.77	3.50				.20	.22	.93	*
830729	175801		.71	.75	3.50				.20	.21	.95	*
830729	175930		1.34	1.58	3.50				.38	.45	.85	*
830729	175945	SPAN HNU			2.00				*	*	*	*
830729	175959	*	*16.8	*16.5	5.00				*	*	*	*
830729	180000	ZERO HNU			2.00				*	*	*	*

APPENDIX G (Continued)

DATE (YYMMDD)	TIME (HHMMSS)	COMMENT	CSI NMOC (PPM C)	HNU NMOC (PPM C)	BECKMAN THC (PPM C)	BECKMAN CO (PPM)	BECKMAN CO2 (%)	BECKMAN O2 (%)	CSI/BEC	HNU/BEC	CSI/HNU	COMBUSTION EFFICIENCY
830729	180023	*	1.47	*.03	5.00				.29	*	*	*
830729	180400	SPAN CSI			2.00				*	*	*	*
830729	180409	*	*15.0	.72	2.00				*	.36	*	*
830729	180600	ZERO CSI			2.00				*	*	*	*
830729	180657	*	*-.55	.69	2.00				*	.34	*	*